CONVERSATIONS

ON THE

ANIMAL ECONOMY.

BY A PHYSICIAN.

IN TWO VOLUMES.

VOL. II.

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CONVERSATION X.

OF THE ORGANS OF SENSE.

VISION.

DR. A.

THE next subject to which I mean to direct your attention, is vision. This is, in many respects, the best understood of any of the organs of sense; and as the operations to which it is conducive, are of a most important and interesting description, and very much within our cognisance, it has at all times received very great attention from men of science. The eye may be considered as an instrument, allowing the entrance into it of rays of light, which, after various refractions, are impinged on its back part, in such a way as to communicate the impression of vision. It consists of a globe or ball, which is lodged in a

socket of bone, and has the optic nerve entering it at its posterior part, through a hole appropriated for the purpose. It has implanted into it various muscles, destined to give it motion, which arise from the bony case which surrounds it.—The bony case, or socket of the eye, is constituted of very thin bones; but the projecting orbit and cheek-bones are thick, are of considerable strength, and are therefore well adapted as a defence to the eye.

CHARLES.

I have heard of serious injuries, and even death being produced, by a push with a foil in the eye in fencing; and I suppose it is from the danger thus occasioned, that fencers frequently wear masks, for the more effectually guarding against such accidents.

DR. A.

Certainly; the eye might not only be seriously injured by a blow or a push, but the bone is little able to resist the application of violence; and hence in a violent lunge, the foil might even penetrate into the brain, and thus occasion death.—The eye consists of a white and coloured part; the former being called the albuginea, or white of the eye; and the latter, the transparent cornea. Within the transparent cornea, is a party-coloured circle, which is called the iris; and in the

centre of this circle is an opening, called the pupil, through which rays pass into the interior of the eye.

HARRIET.

Is the pupil then an opening? I always thought it was a solid black body.

DR. A.

It appears black, just as an opening into a dark cavern, or a dark room, seems so; but if, within the pupil, there should be any change of structure, by which there is an interruption to the passage of rays, and a consequent reflection of light, we then see that it is an opening in the iris.

HARRIET.

But it seems to be extraordinary that the blackness should be so intense; for one would imagine that there would be some glimmering from without, through the coats of the eye; and at any rate, that the rays which pass through the opening, would have some effect in diminishing the extreme darkness of the colour, just as they would the darkness of a room into which they might be admitted.

DR. A.

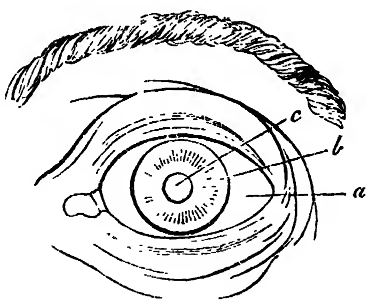
This would unquestionably be the case, unless for a wise provision, which a very slight consideration of the nature of light and colours will enable

you to understand. You will recollect that light, by means of a prism, is capable of being divided into seven colours, namely, red, orange, yellow, green, blue, indigo, and violet. The colour of a body consists in the reflection produced by it, of one or other of those rays, and the absorption of all the rest; while white and black may be regarded as the absence of colour; for in the one, the white, all the rays are reflected, in the other, the black, they are all absorbed. The interior of the eye is lined with a black pigment, which absorbs all the light that might otherwise pass through, or be reflected, and thus interfere with the exercise of vision, and hence arises the intense blackness which belongs to the pupil.

The eye is pretty nearly a ball or globe, composed externally of coats or layers, and internally of substances, more or less fluid, called humours. The whole external surface of this globe, with the exception of the transparent part in front, consists of a white, firm, hard investment, called the sclerotic, having within it the choroid coat, and last of all the retina, or visual part of the eye, which is an expansion of the optic nerve.

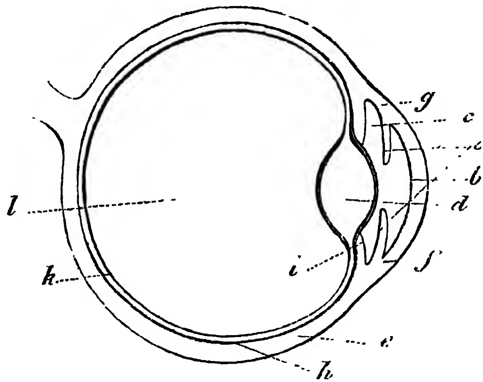
There are thus three coats, which form the principal investments of the eye; and there are also three humours, which fill its interior. The first, or the external, is the aqueous humour, consisting principally of water; the second is the

crystalline lens, or crystalline humour, which is a small, transparent, half-solid mass, lying immediately behind the pupil; and the remaining part of the eye is occupied by the vitreous humour, which resembles very much the aqueous. A couple of little sketches will point out to you what I have endeavoured to explain, relative to the general circumstances of structure of the eye. The division into white, or albuginea (*a*), and transparent cornea, is sufficiently obvious. So is the general shape of the eye, and of the cornea, placed in its forepart, just as if a portion of the opaque sclerotic had been removed to make way for it, and allowing the iris (*b*) and the pupil (*c*) to



be seen through it. Now to understand the interior of the eye, you must suppose a horizontal section of it, and that this is viewed from above. In this section, the iris (*a*) is supposed to be cut across, and to hang in the cavity which is devoted

to the reception of the aqueous humour, dividing this cavity into two parts or chambers; that in



the front (*b*), being called the anterior chamber; that behind (*c*), the posterior.—The aqueous humour is capable of speedy reproduction, when by any accident it may be removed.

Behind, is the crystalline humour or lens (*d*), which is a small transparent body, like a compressed sphere, covered with an exceedingly fine transparent membrane, or capsule, thick and glutinous in the exterior, and gradually becoming firmer and denser to its centre. It is of a fibrous nature, and has been, by some philosophers, supposed to have a muscular structure.

SOPHIA.

This is, I suppose, what comes out of the eye

of a fish after boiling; but in this case, heat must have the power of coagulation, so as to make the substance opaque, which was originally transparent.

DR. A.

Certainly; and the same effect would follow from immersion in alcohol. In both cases it will be found, that there is a pearly part within, which is of a much firmer consistence than that towards the circumference.

SOPHIA.

Is not this the part which is affected in cataract? for I recollect hearing a good deal about the crystalline lens, and an operation upon it, which our neighbour Mrs. S. underwent, some time since, and which restored her sight.

DR. A.

In a cataract there is a change in the character, either of the crystalline lens, the capsule, or both, by means of which they become opaque, and impede the transmission of the rays of light to the retina. The operation consists in either depressing the lens, that is, forcing it into the mass of vitreous humour below; entirely removing it; or carefully breaking down, with a proper instrument, the lens or its capsule, or both, and bringing the portions into the anterior chamber of the eye, where, by being subject to the action of the aqueous

humour, a sort of dissolution of the opaque portions takes place. Subsequent absorption, when the operation is of the latter kind, and succeeds, clears the eye of the obstacles to the entrance of the rays of light.

SOPHIA.

How dreadful must such operations be; and yet I was surprised to hear how well our neighbour bore hers.

CHARLES.

I should imagine, however, that considering the great body of the eye to consist of a fluid, or pulpy mass, there would not be much sensibility internally.

DR. A.

You are quite right. The exquisite sensibility of the eye is to guard it, externally, from the slightest approach of injury; for not only might a wound destroy its organisation entirely, but inflammation, by forming a speck on it, would prevent the passage of the rays to the interior of the eye, and equally interrupt vision. — The crystalline lens is placed in the anterior part of the vitreous humour (*l*), which is a fluid lodged in small transparent cells of extreme fineness, and occupying about three fourths of the globe of the eye. It is surrounded by a very delicate membrane, called the hyaloid membrane, and is not capable of reproduction, like the aqueous

humour, it lost. Being in cells, it appears to have a spissitude which it does not possess. The sclerotic coat (*e*) which forms the external investment of the eye, is so named from its hardness (σκληρωτις, hard). It is thick, tough, and firm, and forms the principal support and protection to the eye. The muscles which move the eye are inserted into it; and it is but little susceptible of inflammation. The front of the sclerotic coat, which terminates at *f*, *g*, has an opening in it, in which is fixed the cornea, extending from *f* to *g*, and so called from its horny texture. It is composed of lamellæ, in which a watery fluid is lodged, which is retained in its position during life and health, giving a plumpness to the anterior surface. At or before the close of life, this fluid oozes out, and forms the obscure film which destroys the transparency of the eye, and forms that most remarkable difference between the activity and brilliancy of this organ during life, and its dull obscured state in death.

HARRIET.

You speak of the sclerotic coat as being little susceptible of inflammation, and yet the white of the eye is frequently blood-shot, and exquisitely sensible to light.

DR. A.

This is from an affection of a subsidiary cover-

ing to the eye, called the adnata, or conjunctiva, which is a reflection of the common skin of the eyelids. It covers the inner surface, and then doubles back to invest the sclerotic coat and the cornea. It is very vascular, and is the seat of inflammation of the eye, or ophthalmia, as this is called.

HARRIET.

But how does it happen that a white surface, in which no redness is at all apparent, should be so far altered, as to become almost like a piece of scarlet cloth; for so I have seen the eye when inflamed?

DR. A.

In ordinary circumstances, the membrane, of which we now speak, is supplied with vessels so minute, as not to admit into them the red particles of the blood, which are, as I shall afterwards have occasion more particularly to notice to you, very small molecules, in which the colouring matter of the blood exists. When by the effects of disease the vessels enlarge, they admit particles into them, which were refused entrance when they were in health; and thus the redness is produced.— Within the sclerotic coat, is the choroid (*h*), which is loosely attached by cellular substance to the sclerotic; is very vascular; is divisible into two membranes; and has a villous or fleecy appear-

ance on the inner surface of the inner one. It secretes a covering of black paint, which, as I have already mentioned, lines the inside of the eye, and indeed may be said to imbue the whole substance of the choroid, in order to absorb any reflected rays which might render vision obscure: various optical instruments are likewise covered with black paint, in their interior, for the same purpose.

SOPHIA.

This covering of paint is of course wanting in albinoes, and in all animals which have red pupils. Since you mentioned the subject at our first meeting, we have had an opportunity of seeing a ferret, and were much surprised and interested with the difference between its eyes, and the ordinary eyes of animals. The whole of the eye which was not white, was of a fiery red; even the iris, which in its usual state is beautifully particoloured; but some of the rabbits had not red eyes, which agrees with what you mentioned to us as occasionally happening, when the other characters of the albino are present.

DR. A.

The choroid coat extends over the vitreous humour as far as the cornea, where it forms the ciliary circle (*i*), and processes. The iris is attached to it anteriorly, and is so denominated from

its various colours. Its posterior surface is called uvea, from having a mucous covering of a dark colour, resembling that of a raisin, which has been regarded as a prolongation of the choroid coat, and secretes a similar black pigment. The office of the iris is to act as a curtain, in order, by its contraction or dilatation, to allow more or fewer rays to pass into the eye, according to circumstances. It is suspended, as I have already mentioned, in the aqueous humour, which it divides into two chambers, and has been supposed to owe its power of contraction to a muscular structure. It does not appear, however, that the circumstances on which this depends are well understood; for contraction is not produced in the iris by the same stimuli which act ordinarily on muscular fibres; as, for instance, electricity or galvanism, or the touch of instruments during operations on the eye. There is, however, this circumstance favourable to the idea of muscular structure, independently of contractility, that it has been ascertained that the iris has all the chemical characters of a muscle, its constituent parts being fibrine, that particular substance of which muscles consist.—The inner membrane or retina (*k*), so called from its net-work structure, is nearly transparent, is exceedingly soft, and easily torn, and is composed principally of a medullary substance continued from the optic nerve. It is in contact with the

choroid coat, without being attached to it, and receives no tinge from its pigment. It is expanded over the vitreous humour (*l*), and is the immediate organ of vision; but it has been found to be without sensibility, when touched by an instrument during an operation. By the microscopic observations which I have already mentioned, the optic nerve has been found to consist of many bundles of very delicate fibres, formed of minute globules, connected by a gelatinous substance; and the retina appeared to be a continuation of such bundles spreading like rays from the nerve to the circumference, where they almost disappear, and end in a smooth membrane. Though the retina is described as being in contact with the choroid coat, and as forming the third coat of the eye, yet, in point of fact, there is interposed between them, a very fine membrane, lately discovered by Dr. Jacob of Dublin, to which no name has yet been given. It is very delicate, almost transparent, and covers the retina from the optic nerve to the ciliary processes, and is common to man with most other animals: this therefore is, properly speaking, the third coat, while the retina is the fourth.

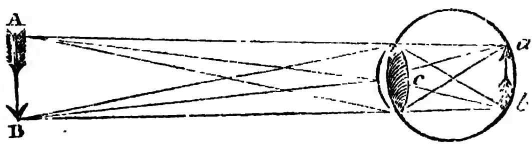
CHARLES.

We may view, then, the eye as a fine optical instrument, in which, for the purpose of conveying

the rays to the proper focus, a complete transparency is as much necessary, as the perfect cleanness and purity of the lenses, in the most perfect telescope or microscope.

DR. A.

The eye is the most perfect of optical instruments. The transparency of the cornea allows the rays to pass from an external object through it, into the pupil. If there is an obscure light, the pupil expands, and admits more rays; if there is a strong light, the pupil contracts, and cuts off an inconvenient portion of them. These rays, proceeding through the crystalline lens and the vitreous humour, undergo the various refractions necessary for giving them such a direction as will make them fall in foci on the retina, from which the impression is conveyed to the sensorium. This may readily be exemplified by a small diagram, in which rays from an object (A, B,) pass through the pupil, and the crystalline lens (*c*), and are impinged on the retina at *a*, *b*.



HARRIET.

I see distinctly how the refraction takes place, so as to effect the union of the rays at the bottom

of the eye. But the image of the object is inverted in the retina. Surely we do not see things upside down?

DR. A.

It is very true that the picture of an object upon the retina is inverted; but it is rather too mechanical an idea to suppose that the impression on the mind ought to be so likewise. In becoming acquainted with external objects, sight and touch go hand in hand in giving us the necessary information. Upper and lower are positions relative to the surface of the earth, and the situations of our own bodies relative to it. After, therefore, we have become acquainted, by touch, with the different parts of bodies, and have learned their position relative to ourselves, we know that by raising our eyes we bring them to a direction which we have been previously informed by touch, refers to the upper part of an object, without any reference whatever to the particular mode in which the impression is communicated. In this way the different situations of the eye, whether elevated or depressed, naturally direct the mind to make a suitable judgment of the situation of objects presented to it.

HARRIET.

Is the union of rays at the bottom of the eye a supposition merely, or has it been the subject of actual observation?

DR. A.

If the eye of a sheep, or any other animal, have the sclerotic coat and the choroid dissected from the retina, and be placed in a hole in a window-shutter, or a box, in such a direction as to admit only the rays from the sun or a candle through the pupil, the image of the object may be actually seen impinged on the retina. It is a matter of some difficulty to have this experiment performed in the best way; but here is the eye of a sheep, from which I have removed the sclerotic and choroid coats, so that you may see the medullary substance of the retina on the soft jelly of the vitreous humour. On shutting the shutters, and bringing near the front of the eye a small lighted taper, you will see the image impinged on the exposed surface of retina behind.

HARRIET.

I see it beautifully represented: and inverted too, just as in the diagram, which we have just seen.

SOPHIA.

This is a very satisfactory experiment, and one which does no harm; for I was afraid that it was by some uncomfortable process that the impingement of the rays on the back part of the eye was rendered evident.

CHARLES.

The usual laws of refraction are I presume

followed, in the passage of pencils of rays through the eyes, just as through any lens.

DR. A.

Certainly; and perhaps you can manage so as to make a little diagram of the mode in which it may be inferred, that the rays will pass on to the retina. You recollect the laws of refraction?

CHARLES.

When rays pass from a rarer into a denser medium, as from air into water, they are refracted to the perpendicular; when from water into air, from the perpendicular.

DR. A.

What would be the effect of rays passing from any object into the transparent cornea?

CHARLES.

If we make a small portion of a circle *a b*, to represent the cornea, and draw a pencil of rays from any object *c*, to the portion of circle at *d*, and passing through it, this pencil of rays, as it goes from a rarer into a denser medium, will be bent to the perpendicular, and the direction will be in *d k* instead of *d f*.

DR. A.

But then rays pass from all parts of an object, to all parts of the cornea; and in what direction would a ray impinged on *e* be directed?

CHARLES.

It would proceed in the direction *e k*, and in time would meet the other ray *c d*, in a focus at *k*.

DR. A.

That, of course, is on the supposition that the medium continues the same; but suppose that it were necessary to have a further refraction, so as to unite these rays nearer the object *c*, how could this be effected?

CHARLES.

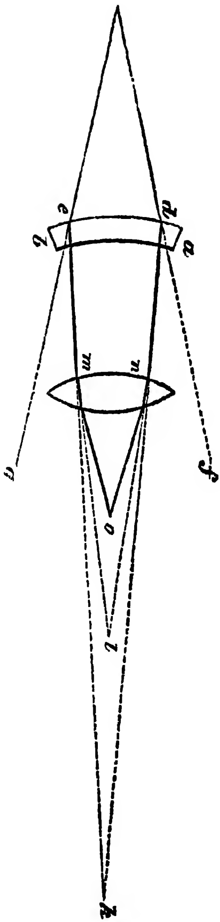
By placing another substance as at *n*, of greater refracting power than the first, in the course of the refracted ray, in order to give it a further bend.

DR. A.

You would then, if the medium were the same, carry the ray on to *l*; but if you were required to unite the rays still nearer the object *c*, the medium not being increased in density, to answer to the increased density of the additional refracting body, you might find a shape in the additional refractor, which would answer the purpose.

CHARLES.

That would be the double concave lens, which, after bending the rays on entering the lens from a


e
d
b
a
m
n
c
f
o
l
k

rarer medium, to the perpendicular, in the direction *n l*, will, on their emerging at the opposite side of the lens, bend them from the perpendicular, and thus alter the direction to *o*, and produce a further convergence.

DR. A.

This is precisely the case with the eye, on which it is necessary that such a refraction should take place, as would produce the union, exactly at the retina, of the pencils of rays which enter it; and there is therefore a necessity for a further degree of refraction being produced, than the cornea and aqueous humour, whose density are pretty much the same, are capable of effecting. This takes place through the medium of the crystalline lens, which is a double convex lens; and it occurs very gradually; for as the refracting power is gradually increased to its centre, (where, as I observed to you, it is firmer and denser than at the circumference,) the curvature which the pencil of rays undergoes is very gradual.

CHARLES.

But then, according to the principles of optics, the focus will not be at the same point, when objects from which rays proceed are at different distances. Has the eye any power of adjusting itself to the different distances of objects, for the purpose of obtaining distinct vision?

DR. A.

It possesses such a power; but philosophers are not altogether agreed upon the mode in which it is exercised. I find, however, that I must defer the explanation of this matter, and the further prosecution of the subject of vision, till our next meeting.

CONVERSATION XI

OF THE ORGANS OF SENSE.

VISION CONTINUED.

DR. A.

You asked me, Charles, when we last met, whether the eye possessed any power of accommodating itself to the different distances of objects, in order to obtain distinct vision; because you very properly observed, that the focus at which rays will unite, at the back part of the eye, will not be at the same point, when the objects from which rays proceed are at different distances. If the curve of the cornea were capable of alteration; or the retina, by some pressure upon the body of the eye which could lengthen its axis, could be made to recede; or if the crystalline lens could be altered in shape, so as to have its curvature changed; or its position in relation to the retina could be made to vary, then a slight degree of consideration will show you, that such an accommodation could be effected as would answer the purpose.

CHARLES.

The alteration of the curve of the cornea seems to be a very natural mode of producing the effect.

DR. A.

And a very effectual one too, if it were found to take place; but though this was rendered probable from some nice experiments made by Sir Everard Home and Mr. Ramsden, on the changes which occur in the convexity of the cornea in viewing objects at different distances, yet, as it was found by Dr. Young, that the eye possesses the power of accommodation when the cornea is in contact with water, and when therefore all the effect of its change of figure would be lost, it is clear that this opinion must be given up.

HARRIET.

I do not quite understand the necessity for the adjustment to different distances which you speak of: perhaps you can make the subject a little more intelligible.

DR. A.

If, in the diagram which I showed you (Vol. II. p. 14.), and to which I must again refer, you place an object nearer to the eye than that which is already represented, you would find that the rays from this second object will condense into a focus before they come to the retina, and thus be indistinct.

You may ascertain the fact by shutting one eye, and while you are looking with a single eye at any object, as that tree, which is about fifty yards from you, hold a pencil in the same direction, at about a foot distance from your eye, and you will find, that while you see the pencil distinctly, the tree will appear indistinct; but if you adjust your eye so as to see the tree distinctly, then the pencil will appear indistinct.

HARRIET.

The thing is now quite intelligible to me. There is a sort of ill-defined edge on the object to which the eye is not accommodated, which the other is without; and if by any of the means which you mention, the focus can be made to be nearer or more remote, according to circumstances, that is, can be made to be in the retina, instead of within or beyond it, distinct vision will, of course, be accomplished.

DR. A.

I have stated to you that no alteration in the curvature of the cornea takes place, so that the effect is not produced in this way; neither can it be proved that any elongation of the body of the eye occurs, which some supposed could be effected by the pressure of the muscles of the eyeball. A power belonging to the crystalline lens of altering its form, either by some muscular operation, or in

some other way, which is not sufficiently understood, was long considered as that by which the phenomenon could be most readily accounted for. But though the lens exhibited something of a fibrous appearance under the microscope, there seemed to be no sufficient proof of its change of shape to settle the point in question. It was formerly supposed that the ciliary processes might be of a muscular nature, and be concerned in the adjustment of the eye, and at Sir Everard Home's request, Mr. Bauer directed his particular attention to the nature of those substances. By examining them in the field of his microscope, he found that there were about eighty of them; that they were about a quarter of an inch in length; had their origin all round the capsule of the vitreous humour, passed over the edge of the lens, and terminated in its capsule, to which they were attached. Sir Everard infers that these processes are of a muscular nature, that they can contract to one half their length, which is, to the extent of one-eighth of an inch, and that by their contraction they can pull back the lens, so as to approximate it sufficiently to the retina, to produce the adjustment necessary.

CHARLES.

This is a very beautiful discovery, but can

microscopic observations be sufficiently depended upon to settle such a difficult question?

DR. A.

There is no question of Mr. Bauer's skill in the use of the microscope, and his accuracy of observation; and, setting aside the difficulties which are connected with the study of organization so minute, there is much appearance of truth in the deductions which Sir Everard has made on this subject.

HARRIET.

You mentioned the cure of opacity in the crystalline lens, by the depression or the removal of the lens. If the patient had the same power as before the operation, of accommodating the eye to different distances, this would be against the idea that an alteration in the form or position of the lens produces the adjustment.

DR. A.

This, however, is not the case; for it has been found after such an operation, that the eye had not the same power which it originally possessed; and that the assistance of glasses is necessary, in order to produce distinct vision at different distances.

CHARLES.

Have any calculations been made of the re-

spective quantities of refractive power possessed by the different parts of the eye?

DR. A.

From experiments made on this subject, it would appear, that the refractive power of

Atmospheric air, is	-	1·00032
Water	-	1·3358
The aqueous humour	-	1·3366
The central part of the crystalline lens	-	1·3990
The whole lens	-	1·3839
The vitreous humour	-	1·3394

CHARLES.

As there are two images of every object presented to the inward sense, I suppose there is some sort of sympathy or accordance between the two eyes, which enables them to see an object as one, and not two.

DR. A.

And yet you may very readily, by a little management, see the same object, either as one or two. If you put two candles on a table, at different distances from the eye, and in the same line, it is clear that you can see both of them at the same time. Let us try the experiment. Now attend, Harriet, to the further [illegible], how does the nearer appear to you?

HARRIET.

I see two images of the nearer one.

DR. A.

Look next at the nearer candle, and what appearance does the further make?

HARRIET.

I now see two images of the further one.—This is exceedingly curious; but is the same circumstance applicable to all objects seen at different distances?

DR. A.

Certainly so; but the subject does not strike us at once, from the circumstance of the object to which the eye is directed, being the principal, or indeed the only one attended to in ordinary circumstances. A certain power of accommodation of the two eyes to one object, is therefore necessary to correct vision; and many intoxicated persons, or those who have lost the command of their eyes in certain diseases, see objects double.

SOPHIA.

But I cannot understand why, at one time, two images on the retina should give the perception of one object; while, at another, they should give the perception of two.

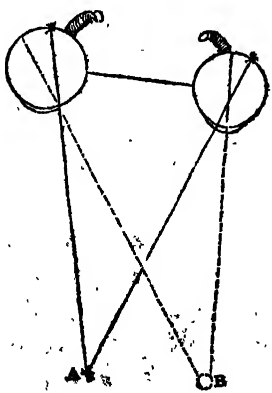
DR. A.

The question is difficult, and has given rise to a

good deal of controversy. In order to understand it, it is necessary to consider some circumstances relative to the motions of the eye. The axis of the eye is a straight line, which is supposed to pass through the centre of the pupil, and of the crystalline lens, and to fall on the middle of the retina: in viewing an object, we turn our eyes in such a way, as that the axis of each eye will, when protracted, meet in the centre of the object. But if we turn one eye to an object, the other is instantly turned to the same object. We cannot move one without the other; and we may feel that if one of the eyes is even shut, it follows the motion of the other, just as if it were open: this is called the paralell motion of the eyes. But you will easily understand, that the natural motion in vision cannot, under any circumstances, be precisely parallel; because the rays which fall upon the retina of each eye, form an angle in the object from which they proceed, and therefore diverge in going to the eye. You will likewise see that the greater the distance is that the object is from the eyes, the more nearly parallel will their motions be.

Now the most sensible part of the retina is at the centre of each eye; and when the eyes are turned to the same object, the rays are necessarily impinged upon such centre, and you have perfect and single vision. But if you press, with your finger, one of the eyeballs, in such a way as that

the rays should not fall upon the centre, then you have double vision produced. There is, therefore, some sympathy or correspondence, whether natural or acquired, between the centres of each retina, by means of which an image falling on both of them, conveys to the sensorium the impression of one object only. The centres of each retina, therefore, *correspond*, as it has been termed, with each other. You will readily understand this, by a diagram, in which two globes, having each the optic nerve at their bottom proceeding from them, represent the two eyes, turned both of them to the object (A).



It is obvious that a straight line from (A) will fall on the retina at its centre, just as far from the optic nerve of the one eye, on one side, as from

the optic nerve of the other eye, on the other. Under such circumstances, distinct and single vision are produced. But if you move the globe of one eye, so as that rays from the object (A) will not pass through the centre of the pupil and of the lens, and will be impinged on the retina of one eye, at some distance from the centre of the retina, while in the other they are impinged on the centre of the retina, then double vision is produced. The rays do not, in this case, fall upon points of the retina which are corresponding.

SOPHIA.

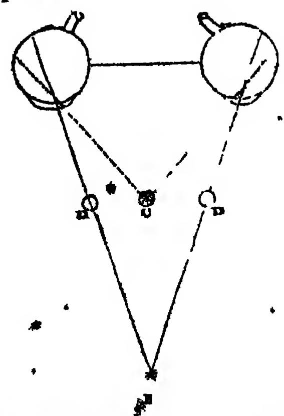
You have made this very intelligible as far as the centre of the retina goes, or the point into which the axis of the eye enters; but then all objects which we view, and every part of the same object, are not at one point; and therefore the impingement must occupy some sensible space of the retina, which must be greater or less, according to the magnitude or number of the objects seen at one time.

DR. A.

If the object (B) be placed at one side of the object (A), and on the same plane, it will be seen single, as well as the object (A); and the rays proceeding from it will proceed to the retina in the direction of the dotted lines.

Now consider under what circumstances single vision is produced. It takes place if the rays are

impinged on the centre of the retina; but it likewise occurs, if rays fall on the retina, at the same side of the centre, and at equal distances from it, as is the case with the dotted line. The centres of the retina, therefore, and such parts of it as are at equal distances from the centre, on the same side, correspond with each other, and are termed *corresponding points*, and if rays fall upon them, single vision takes place.



In the case of the candles seen at different distances, suppose you look at the more distant (B), the candle (C) is seen double, and the images appear as if the objects were at (D D), but the rays fall from the candle (C) on the retina, in the direction of the dotted lines; that is, on opposite sides of the centre of the retina, instead of the same side, and double vision is the consequence.

HARRIET.

When the eye is distorted as in squinting, do people see double? I never heard of this being the case, though it seems as if it should be so, according to the system of corresponding points.

DR. A.

People do not see double in squinting: and it would therefore seem probable, that when the distortion is a very slight one, there has been a power exercised by the eye, of having certain points made corresponding, which were not originally so. This, of course, involves the consideration of whether points were corresponding by an original law of our nature, or by the effects of habit and experience. In general, however, when people squint, the distorted eye is turned so far to one side, as not to receive rays from the object seen by the other; so that, in this case, one eye is for the most part only employed, and double vision of necessity not produced. But it is to be remarked, that a distorted eye is generally weaker than a sound one; and in such a case, the stronger impression of the sound eye is principally attended to: that of the weak is comparatively overlooked; and a distortion spontaneously occurs, in order to cut off the rays, and avoid confusion.—The conjoint operation of both eyes is not merely useful for increasing the strength of impression. In

many instances it likewise facilitates the power of direction, as you will find if you try to thread a needle, or to introduce a stick into a ring, with one eye instead of two.

SOPHIA.

For the sempstress's operation, I flatter myself that I may be some authority; but I am really surprised at the difficulty of hitting the eye of the needle when one eye is shut. I should have been inclined to expect more, rather than less precision with one eye, if the trial had not undeceived me.

DR. A.

There is a remarkable circumstance connected with impingement on the retina, which was discovered by the Abbé Marriotte; it is this, that such rays as fall on the part where the optic nerve enters the eye, and pierces the sclerotic and choroid coats, for the purpose of being diffused over the latter, in the form of retina, is insensible, and presents no image to the mind.

SOPHIA.

This is exceedingly curious. But how can this point be rendered evident?

DR. A.

It can very readily be done; and for this pur-[illegible] I shall put three small pieces of white paper [illegible]the wall, at about two feet distance from each

other. Now, stand opposite the middle paper, at the distance of four feet, and shut your left eye, holding your finger upon it. Look at the left-hand paper with your right eye. You see the whole of the three portions of paper, though, of course, the left hand one more distinctly.'

SOPHIA.

Certainly.

DR. A.

Keep your body in the same position, and retire gradually. You are now about seven feet from the wall, but do you see the middle paper?

SOPHIA.

I do not, though I see each of the others.

DR. A.

Retire a yard or two further back.

SOPHIA.

I now see the middle paper, and both the others likewise; so that it is clear, that the rays proceeding from the middle paper, while I was at the distance of seven feet from the wall, though they fell on the eye, were not actually seen.

DR. A.

The reason of this is, that the optic nerve enters the eye, rather to the inside of the centre of the retina; and when you retired, keeping the eye steadily on the left-hand paper. the rays from the

middle one fell on that part of the eye where the optic nerve enters, as you might easily convince yourselves, by varying one of the diagrams which I have shown you. The third paper is only necessary for greater distinctness; for the same circumstance is equally demonstrable with two portions. But the experiment may be varied, so as to show the insensibility of the same portion of both eyes at the same time. Thus, put two pieces of paper, Harriet, at the distance of three feet from each other on the wall, and retire to the distance of 12 or 13 feet. Keep your eyes on the paper, and hold a finger upright, about eight inches before your eyes, still viewing the papers.

HARRIET.

My finger appears double, the paper is single.

DR. A.

Of course; but you will find that there is a position, in which your finger will conceal from the right eye, on your shutting it, the view of the left hand paper; and from your left eye, on your shutting it, the view of the right hand paper. Keep your finger in this precise position, and look at it steadily with both eyes.

HARRIET.

I now lose sight of both papers; so that the rays must have fallen on an insensible part of the

retina in both eyes. But why should this be the case? for I should have expected, that the nerve itself would have been endowed with all the sensibility of the part derived from it.

DR. A.

Philosophers were much puzzled about this circumstance, when it was first known; and some were disposed to consider the choroid coat as the peculiar seat of vision; because it was wanting in this particular spot where the nerve penetrated. But your difficulty is removed by the consideration, that the nerve itself is not the organ of vision, but the expansion of the nerve; and that we might as well expect the nerve, in any part of its course from the brain to the organ; or even the brain itself, as the source of the nerve's energy, to be endowed with visual power, as that the nerve should possess it at this particular place, where the formation of the organ is only to commence.

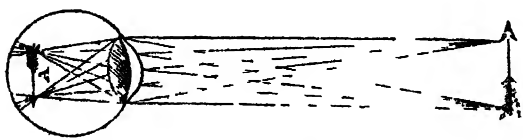
HARRIET.

How beautiful and perfect an instrument must the eye be, when it is considered, that the minutest object of a large landscape is correctly painted on so small a space as the retina must be, with all the vivid colours of nature; but I suppose there are varieties in the perfection of the instrument, or its fitness for producing the due impression on the mind.

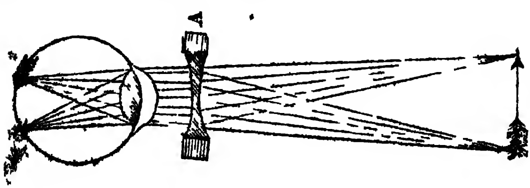
DR. A.

The instrument is perfect when the rays pass through the eye without interruption, and unite in a focus upon the retina. But then, with some, the refractive power of the eye is so great, as produce the convergence on the retina too soon. This is called short-sightedness, or myopism, from mice being supposed to have such kind of sight; whereas, on the other hand, when the rays are not brought to a focus with sufficient readiness, presbyopism, or long-sightedness, is produced.

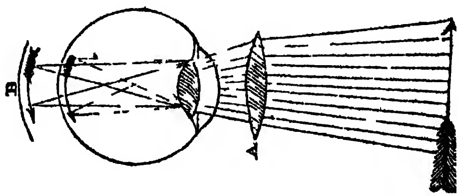
This will be readily understood from a diagram, in which an image is formed at A, before the rays reach the surface of the retina, so that they again begin to diverge; and these diverging rays give the indistinct vision of a short-sighted person.



A double concave lens (A) makes the rays diverge, and thus retards their convergence into a focus to the requisite extent.



In another diagram the rays, as at B, do not converge sufficiently soon, and therefore require the additional refraction which the double-convex lens A affords.



So that, in the short-sighted, the object is to diminish, and in the long-sighted to increase, the refraction exercised on the rays which are admitted into the eye.

CHARLES.

The diminution of the power of refraction in the eye is, I imagine, a symptom of the approach of age.

DR. A.

It is termed presbyopism, from being the common defect of old people, and it is one of the earliest marks of failure in the natural powers. With me, you may have observed, that the nice operation of nibbing a pen, and reading very small print, has, for some time past, required the assistance of a glass. Around the nib of the pen there is a slight confusion, owing to the rays not con-

verging into a focus at the usual distance from the eye, and a glass of slight power removes it; while both in doing this, and in reading small print, the distance at which the focus could be correctly made, would be beyond that at which small objects could be readily seen; and therefore the assistance of a glass, of more or less magnifying power, is required. — Sometimes it has happened, that one eye has been myopic, and the other presbyopic, so as to require glasses of different nature for the purpose of obtaining perfect vision.

CHARLES.

Does the eye lose power in advancing life, independently of the altered faculty of accommodation?

DR. A.

When the nervous sensibility of the eye, that is, the power of the retina to communicate impressions to the sensorium, is gone, or diminished, then blindness, in various degrees, takes place; and one usual consequence is the more or less expanded state of the pupil, and its diminished, or total insensibility to the action of light.

But there is a very singular natural defect in the eyes of some persons, altogether independent of disease; and that is the want of the power of discriminating certain colours. A curious story is told of a Glasgow student, who could not distin-

guish between red and green; so that it used to be a common trick among his fellow-collegians, to throw his red gown (which he wore as a student) upon the grass, in order to enjoy his difficulty in finding it. — Dr. Priestley mentions a case in the Philosophical Transactions, in which a similar difficulty of distinguishing between red and green existed; the person being able to discover cherries on trees, only from their differing in size and shape from the leaves. He could distinguish a difference in stripes; but all light colours he described as white, and dark ones as black. Two of his brothers had defective vision; one of them calling light green, yellow; and orange, the colour of grass. — Dr. Priestley's case was the means of another being brought forward, in which pink and pale blue appeared alike, as did full red, and full green. The person could distinguish all shades of yellow and blue, except pale blue; but full purple and deep blue sometimes baffled him; and claret colour appeared like black. This person's father, one of his sisters, and an uncle on the mother's side, had a similar defect; as had two sons of his sister, but her daughter had perfect vision. — Dr. Nicholl, of Ludlow, has described two curious cases of this kind, which came within his own particular observation. In one of them, a young gentleman of 10 years of age, could not distinguish green; but with the exception of dark bottle-green,

which he called brown, he termed other greens red. Red and blue he could discriminate; but light red and pink he called light blue; light yellow, yellow; and darker yellows, and light browns, he confounded with red. Grass, and green baize, he considered of the same colour; and once said, that he knew fowls were contained in a butter-basket, carried by a countrywoman, from seeing the red feathers hanging out, which proved to be green leaves with which her butter was covered. The only colours which he could discover in the prism were red, yellow, and purple. The young gentleman's maternal grandfather had a similar defect, and being in the navy, once purchased a blue uniform coat and waistcoat, with *red* breeches, to match the blue. Green he always confounded with red. A brother of the grandfather had a similar defect, and has mistaken a cucumber for a lobster, and a green leek for a stick of red sealing-wax. — Dr. Nicholl's second case is nearly similar; grass being always regarded as red, and fruit undistinguishable from leaves, except by the shape; and in no other member of the family had such a defect been known, except in the daughter of a brother.

SOPHIA.

It is very curious that all those cases agree in confounding green with red.

DR. A.

This is a very remarkable circumstance, and it accords with the only case of a want of power of discriminating colours which I ever personally knew, that of a clergyman, who could not distinguish between the red rose, and the green leaves of the rose-bush.

CHARLES.

These cases are likewise interesting, as confirming what you mentioned, relative to the transmission of accidental peculiarities of structure.

DR. A.

Undoubtedly; and the more accidental peculiarities are attended to, the more are they likely to be found appertaining to particular families.

SOPHIA.

You mentioned that the expanded state of the pupil, and its diminished sensibility to light, were connected with a diminished power of the retina, or with various degrees of blindness. The iris, then, I suppose, must be considered as a sort of guard to the internal parts of the eye, to prevent too much light from passing into them.

DR. A.

Certainly; and hence, according to the degree of light, the iris will contract, so as to intercept, or expand, so as to admit light. You may see this

in one of your eyes very distinctly; and when I even hold my hand before Charles's eye, and remove it suddenly, the contraction of the pupil is instantly seen.

In some animals, where there is a necessity for occasional exposure to strong light, there is what is called a membrana nictitans, or winking membrane, which the animal has the power of expanding over its eye, so as to intercept the light, and place the eye, as it were, behind a curtain. When not employed, this membrane lies in the corner of the eye; and it is expanded by means of two muscles, when its protection is necessary.

HARRIET.

I have observed this frequently in the parrot.

DR. A.

It is common to all birds, and is most perfect in birds of prey, with which there is a necessity for looking at, or very near the sun. It likewise exists in cats, and all animals of that genus; in the opossum; in the seal; and in the elephant. There is a rudiment of it in man, at the inner canthus of the eye; and this is still greater in the horse. But in some fish, as the skate and thornback, there is a sort of curtain, at the upper part of the pupil, which is capable of being let down, at the pleasure of the animal, so as entirely to exclude rays from passing through it.

SOPHIA.

The pupil in all animals does not seem to be round. In the cat, for instance, it is oblong, and is capable of extraordinary changes of shape.

DR. A.

It is vertical in some animals, as in those of the cat kind; and transverse in others, as the ruminant animals, horses, &c.; and this sort of construction allows of a more varied contraction and expansion, than by means of circular fibres only; and therefore gives to an animal the power of employing the eyes in very bright, or very obscure lights, with great effect. The contraction or dilatation of the pupil is in some degree under the influence of the will; and with gentlemen who are much in the habit of experimenting with the eyes, the faculty is capable of considerable increase, so much so as to admit of dilatation against light, or contraction in gloom.

CHARLES.

Do you imagine that there is as much difference in the visual faculty in animals, as there is in their smell? I should imagine that this must be the case, if it be true, that birds of prey can discover the animal which they intend to attack at a great distance.

DR. A.

I have no doubt that your idea is correct, for

Nature has very wisely adapted the strength of all the faculties to the habits of the animal. The eyes of the eagle are proverbially acute; and birds of prey generally have extraordinary powers of vision. It is stated in the Philosophical Transactions, by Sir Everard Home, that an hour after a wild hog was killed, in India, and long before there could be the least odour from putrefaction, a dark spot was seen in the heavens, which proved to be a vulture making directly for the carcase of the animal. Soon afterwards, similar specks were seen; and seventy other vultures speedily made their appearance. Dr. Russel states having observed at Aleppo, in serene weather, when not a speck was to be seen in the sky, that if any dead animal was left behind by hunting parties, in the space of a few minutes it was surrounded by birds, although none were visible previously. The eyes of such kind of birds must likewise have a great power of accommodation, since they are equally adapted to great distances, as to the small ones which must intervene between their eyes, and the prey which they attack.

CHARLES.

Where there is the great power of accommodation which you mention, is there any peculiar apparatus for the purpose of effecting it, which man does not possess?

DR. A.

As far as the structures agree, there is every reason to suppose that the same circumstances apply to the human and other eyes; but in many birds there is a rim of scales lying over the junction of the sclerotic and cornea, which has been imagined, but without sufficient evidence, to be concerned in effecting accommodation, by the elongation or shortening of the axis of the eye, according to circumstances. There is likewise, in birds, a point of minute structure, which some have supposed to tend to the same purpose. It is that of a fine membrane, rising in the back of the eye; proceeding, apparently, through a slit in the retina. It forms a sort of fine bag; and being imbued with black paint, like the choroid coat, it is termed the marsupium nigrum, or black purse. It passes obliquely into the vitreous humour, and terminates in that part, reaching frequently to the capsule of the crystalline lens.

SOPHIA.

As the medium occupied by fish must be nearly of the same density as the aqueous humour of the eye, one would imagine that the latter would be useless as a refracting organ.

DR. A.

You are very right; and therefore in fish, and some quadrupeds and birds which are much in

the water, as seals and cormorants, the crystalline lens projects through the iris, so as to leave very little room for aqueous humour; for in them it would evidently be of no use. But in order to make up for the want of this as a refracting medium, the crystalline lens in fish is more of a sphere than is usual in the other classes, and thus has a greater refractive power. On the other hand, in birds, which spend much of their time in a somewhat elevated region, where the medium is rarer than at the surface of the earth, the aqueous humour is in considerable quantity.

Fish have been described by some physiologists, as having a small muscular organ connected with the choroid coat, the use of which is to assist in accommodating the eye to different distances. You may thus see, however, that much as is known about the eye, a great deal is still to be ascertained relative to its minute structure.

CHARLES.

You mentioned the great power of dilatation, which the oblong shape of the pupil affords to animals which have occasion to use their eyes in obscure lights; but is mere dilatation of pupil sufficient to enable them to see in the dark?

DR. A.

This will only go to a certain extent; but there is a curious provision for seeing in the dark, which

such animals have, and that is, that the inner membrane of the choroid coat, instead of being covered, on its inner surface, wholly with the black paint which I have mentioned as belonging to it in man, has a greater or smaller proportion of it of a pearly white, or of a yellow, green, blue, or variegated colour, by means of which there is a reflection, instead of an absorption of rays, from the bottom of the eye. In the cat, and animals of the cat kind, which prowl about at night for their prey, this is eminently the case; and their eyes occasionally glare in the dark, when the pupil is much enlarged, by the reflection of light from the lucid covering which I mention, and which is called the tapetum lucidum or lucid carpet. Horses have likewise a coloured, instead of a black surface, and they are thus enabled to see their way in the dark, when their riders are at fault: this is also the case with cows, sheep, dogs, and various other quadrupeds; but birds are without it, as are fish, with the exception of the skate; and this is rather remarkable, for it might be imagined that fish would have occasion for every means of increasing light, in pursuing their prey, or in looking out for an enemy at great distances, and at vast depths.

HARRIET.

But are we to suppose the faculty of seeing durring the day, diminished by animals being endowed

with such a peculiarity of organ, as enables them to see in a superior manner during the night? For as the total darkness of the interior of the human eye is advantageous to it, as an optical instrument, and is well adapted to its seeing well in ordinary light, one would imagine that the same must be the case with the eyes of other animals.

DR. A.

There is certainly a difficulty in the point which you mention, that has not been altogether cleared up; for though some of the human race who have the peculiar defect of sight which is called night vision, and see best at night, see imperfectly during the day, yet some of the animals which I have named to you, particularly the cat, have very keen vision as well by day as by night. It is very possible, however, that the eye of man may derive the accuracy and precision which fit it for the particular examination of minute objects, and which are unnecessary in other animals, from the impingement of rays on the retina being unaffected by reflection from the neighbouring chor id. — We have been lately informed by two eminent French physiologists,* that in fish which require to see well in the depths of the ocean, and in such birds as have occasion for accurate vision at great distances, there is an amplification and extension of both the retina and

* MM. Magendie and Desmoulins.

optic nerve in the interior of the eye, by means of a sort of fold or doublings, which give a greater extent of sensible surface, and therefore augment the power of this organ of vision.

I must not omit to notice to you, the very remarkable eyes which are possessed by insects, and which are so unlike any which exist in the higher orders of animals. Some insects have simple eyes, that is, eyes which seem composed of a single lens; in others, these simple eyes are collected into a body, and these have been termed conglomerate. But the most extraordinary are the compound eyes, which are those possessed by most insects, and which, with the glass, present an appearance resembling shagreen. This arises from the eye being traversed with numerous dark lines, cutting each other at right angles, and forming little squares, within each of which is set a six-sided convex lens. The inside of these lenses is covered with a black varnish or paint; and behind this, are minute white threads, of the shape of hexagonal prisms, which fit into the groove formed by the sides of the hexagonal lens, and are separated from the latter by the black varnish. The threads are inclosed in a black unvarnished membrane, on which the optic nerve is expanded, and from which they are derived; so that they may be regarded as the retina of the eye, and the dark membrane, as the choroid coat. But it is difficult to

perceive in what way vision is produced by an impingement on a retina, having black paint interposed between it and the rays which are to be the subjects of observation. If you examine the head of a fly with a pocket glass, the appearance of shagreen will be very apparent.

HARRIET.

It is quite evident, but I cannot make out the lenses which you describe.

DR. A.

This is owing to the black paint which lies below them; but here is the head of a dead fly, divided in such a way, as to separate the shagreen surface from the parts below. On placing this in the field of my little microscope, and throwing some light upon it, you will have the brightness of the lenses well defined.

HARRIET.

Beautifully so; but they seem to be rather shining points than to possess any well described figure.

DR. A.

This is from the power of the instrument not being quite sufficient to give you the full effect of this appearance, and of the shape of the hexagonal prisms of nervous matter, which I have mentioned

as being continued from the lenses, and which appear as slender, light coloured threads.

SOPHIA.

But what a number of these little lenses there must be. They seem to be innumerable.

DR. A.

They vary in different insects, some have very few, not more than fifty; but Hooke computed those in the eye of a horse-fly to amount to nearly 7000; Leeuwenhoeck found more than 12,000 in that of a dragon-fly; and still more have been observed in the eyes of butterflies. It is to be presumed, that the number and minuteness of those lenses are necessary to that microscopic nicety of vision, which insects must have, in order to provide food, and avoid injury. As their eyes, too, are without motion, a structure such as that which I have now mentioned, was wanting for the reception of rays from all directions. — The appearance of the opaque substance below these lenses, produces the beautiful metallic hues, for which the eyes of some insects are remarkable.

The remarks which I have made relative to the eye, refer principally to it as an organ of vision; but there is much curious structure external to the eye, for the purpose of giving it motion, and affording it protection. — For the first purpose, six

muscles arise from different parts of the orbit, and are implanted into the sclerotic coat, which produce the varied movements of which the eye is capable. In order to protect the eye, the eyelids are, in the first place, the principal agent. These have a ready motion, and a peculiar watchfulness and sensibility, so that they, and the edge of hair by which they are bordered, and which are called the cilia, or eyelashes, continually guard the eye from the introduction of irritating matters from without.

HARRIET.

The tears are produced, I suppose, for the purpose of washing out any irritating substances which may get into the eye?

DR. A.

This is not the only use for which they are intended, for they also serve to keep the eye moist. They are secreted from a gland known by the name of the lachrymal gland, which lies under the orbit, at the upper and outside of each eye. The secretion from this gland is continual, even during sleep; and is carried to the surface of the eye, by several small ducts or tubes, which open upon the inner surface of each eyelid.

HARRIET.

But then if the secretion of tears is continual,

how does it happen, that the eye is not perpetually weeping? In the day-time, evaporation might be supposed to carry off the superfluous fluid; but during sleep, when the eyelids are closed, this could not take place.

DR. A.

Your question is a very pertinent one, and I shall explain to you how this occurs. The eyelids are edged by cartilage or gristle, which keeps them regularly expanded, and allows them to shut closely upon each other; but this accurate approximation is only on the fore-part; for behind. there is a small conduit, which conducts the tears to two small orifices, called puncta lachrymalia, or lachrymal points, one situated at the extreme inner edge of the upper, and the other at that of the lower eyelid. You may see, by careful examination, a small point on each eyelid, which are the points mentioned by me.

CHARLES.

You mean at the very projecting part, where the rudiment of the nictitating membrane commences.

DR. A.

Exactly so. These orifices have cartilaginous margins, so as always to keep open. They are thus ready for absorbing the tears, and are so

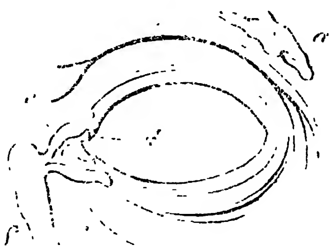
small, as to act by capillary attraction, that is, as you may recollect, by the particular property of very small tubes, of sucking up a fluid without any particular external agency.

SOPHIA.

But then where are the tears carried to?

DR. A.

These orifices lead, by two small ducts, into a little sack or cavity, of a longitudinal shape, which terminates in a duct, opening into the cavity of the nostrils, where the fluid is diffused over an extensive surface, and evaporated by means of the air passing continually over it. When these ducts, leading from the eye to the nose are ob-



structed, the eye becomes weeping, and that particular complaint is produced, which is known by the name of fistula lachrymalis, or lachrymal fistula. You will be able to understand this from a little sketch, which I now show you, in which *a* is the lachrymal gland; *d d*, the lachrymal points; *e e*, the lachrymal ducts; *f*, the sac; and *g*, the duct leading into the nose.

CHARLES.

How very beautiful is all this contrivance; and indeed a little consideration might convince us of the communication between the eye and the nose, when we find that a considerable portion of fluid is thrown into the cavity of the nostril in weeping; and that this secretion is increased by any irritating substance getting into the eye. But how is the eye, which is so sensible to ordinary irritation, and the passages which you have mentioned, guarded against the continual agency of the saline fluid, the tears?

DR. A.

This seems to be, by the secretion from the various surfaces to which they are applied; and in the case of the eye-lashes, by a sebaceous or fatty matter, secreted by small glands, situated under the inner membrane of the eyelids, and having tubes, through which their secretion is carried to their cilia or edges, which are, by this means, kept fit for accurate approximation. These glands

are the seat of sties in the eye; and when their secretion is much increased, as in inflammation of the eyelids, the eyes are often nearly glued up by their increased secretion.

HARRIET.

One would imagine that animals which live in water, and have, therefore, the eyes kept always moist, would not require tears, as those who live in air do.

DR. A.

And therefore they are without any part of the apparatus for secreting them; for nature, while it does not withhold proper accommodation, gives no organ which is unnecessary or useless.

SOPHIA.

The motions of the head seem to be well calculated to assist the eyes, and to enlarge the sphere of vision; but I suppose the eyes have their position directed by nature, according to the wants and character of the animal.

DR. A.

Certainly: in man, and some other animals, the eyes are placed chiefly to look forward, but at the same time so as to take in nearly a whole hemisphere. In birds, their lateral position enables them to embrace almost a sphere, in order the better to assist them in discovering food, and announcing

danger. In hares and rabbits, the eyes are not only very prominent, but are placed so as to look behind as well as before, and thus to see an approaching enemy; while dogs, whose habits are rather to pursue than to avoid, have their eyes set more forward in their head.—I have already mentioned the immensity in number of the eyes of many insects. Spiders have no motion in their heads, and have four, six, or eight eyes, to increase their sphere of vision, which are placed in every variety of form in different species. The snail has four, but they are inserted at the extremity of their horns, the motion of which enables them to be turned in all directions. The lobster likewise has no motion in its eyes, but they are situated at the end of two moveable peduncles, so as to be turned in various directions.

There is an interesting circumstance relative to our appreciation of the direction of eyes, which I must not omit to mention to you before I take leave of vision. We are sensible, of course, when the eyes of any person are fixed upon us; and we have a perception of the exchange of even a momentary glance.

SOPHIA.

Assuredly.

DR. A.

But in what way do we form this opinion?

SOPHIA.

By observing that the eyes are directed to or from us?

DR. A.

This is no doubt the case; but then is it by means of the eye itself, or by the relation which the eye bears to the other features, that we come to this conclusion?

SOPHIA.

I should think the eye itself must give us the necessary information; for it is to this that the attention is particularly directed: though I must own I have never made this a subject of particular remark.

CHARLES.

One is certainly very apt to conceive, that the eye may be contemplated separately from the other features; but yet it would be difficult, if not impossible to do so; and you therefore stagger my confidence in my first apprehension as to the facts of the case.

DR. A.

It has been proved by Dr. Wollaston, who is one of the most distinguished philosophers of the present day, that if a pair of eyes be drawn with correctness, looking at the spectator, unless some touch be added to suggest the turn of the

face, the direction of the eyes seems vague, and so undetermined, that their direction will not appear the same to all persons. If to such eyes particular features be appended, they may be made to appear directed either to him, or from him, in a manner perfectly unexpected. Dr. Wollaston, therefore, infers, that as in the portraits of eyes, we judge of the direction by the concurrent position of the entire face, we do the same with regard to the eyes of living persons. He exemplifies his doctrine in a manner equally ingenious and satisfactory, by some sketches, annexed to his paper in the Philosophical Transactions for 1824, p. 260. To a pair of eyes, with the eyebrows drawn from the life, by Sir Thomas Lawrence, intently looking at him, a turn of face was added, so that the eyes, with this accompaniment, appear decidedly looking at the spectator, though indistinctly so without it. By means of a flap, a set of features oppositely turned, are so applied to the same eyes, that they look considerably to the right of the person viewing them.

HARRIET.

How exceedingly curious this must be; it would be hardly possible to believe them to be the same eyes.

DR. A.

No one would, unless with complete evidence

of their identity; and in four other sketches of the same eyes, two of them have their apparent direction altered by the mere position of the nose; and in the others a corresponding difference is effected solely by means of the upper half of the face. The same would happen if the eyes, instead of being drawn originally looking directly at us, were made to look a little to one side of us; in which case they might be made to look at us, by applying other features in a suitable position.

CHARLES.

But I presume this very striking effect is limited to small differences.

DR. A.

Certainly, to changes of perhaps 20 or 30 degrees; for, as Dr. Wollaston remarks, it would be absurd to imagine, that an eye drawn in profile, could be made to look full on us; or that an eye looking nearly at us, could be made to appear as profile. — But Dr. Wollaston likewise observes, that a total difference of character may be given to the same eyes, by a proper representation of other features; and that a lost look of devout abstraction, in an uplifted and interesting female countenance, may be exchanged for an appearance of inquisitive archness, merely by giving to the face a direction downwards, and to the opposite side. I must refer you to the original paper, for

an illustration of all the circumstances which I have mentioned; but the change produced on the female countenance, in the way mentioned, illustrates Dr. Wollaston's principles so well, that I have made a sketch of it for your inspection. In this sketch, the alteration of features, produced by the removal of the flap, must appear to you wholly unlooked for.

SOPHIA.

The effect is exceedingly striking, and seems a perfect delusion.

HARRIET.

If the sketch with and without the flap were shown, we should believe the two representations of countenance entirely distinct and independent; but seeing them together, we are constrained, against the evidence of our senses, to believe them the same.

SOPHIA.

The whole circumstances are highly interesting; but I think Dr. Wollaston has been rather bold, in taking from the eye its long possessed dignity of independent lustre and expression, and dividing these oft-sung attributes, with the unpoetical organs of nose and chin. It must have required, I think, all the merciful consideration of his female friends, to pardon such an offence against the acknowledged majesty of the eye.

CONVERSATION XII.

OF THE ORGANS OF SENSE.

HEARING.

DR. A.

THE next of the organs of sense which I intend considering, is hearing, which is the sensation communicated to the nerves of the ear, principally by means of vibrations of the air transmitted from the sonorous body. These vibrations, or undulations, are collected by the external ear, in a sort of trumpet-like tube, at the extremity of which is a cavity called the drum of the ear, or the tympanum, which is filled with air, and is covered by a membrane called the membrane of the tympanum. The undulations act on this membrane, and through its means on a curious bony structure situated in its cavity; while the impressions are, by the last bone of the series, propagated to what is termed the internal ear, which consists of several small cavities, filled with water, and having the delicate terminations of the auditory nerves diffused over them.

CHARLES.

There seems, therefore, to be the same plan followed by nature in the arrangement of the auditory, as of the visual functions; the more external parts being destined to receive and communicate impulses from without, to the more internal parts, which are the immediate organs of sense.

DR. A.

The funnel-like tube, and the irregular surfaces of the outer ear, collect and concentrate the undulations of the air, so that they may act with greater force on the membrane of the tympanum. The external ear, in most animals, has also a considerable agency in this operation; for its concave surface is placed, at the will of the animal, in the direction from which sound proceeds, in order to intercept a greater portion of the waves or undulations. Among the more civilized nations the ears are so much tied down, as entirely to lose the power of motion.

SOPHIA.

But do you suppose that we should have the power of moving our ears like dogs or horses, except for this early habit of binding them down?

DR. A.

Certainly not to the same extent, because the

ears are neither of a similar size nor shape; but some eastern nations have a considerable power of motion in theirs; and in some ancient statues they project considerably, which adds to the expression of the head. Many people have the power of producing an obscure motion in the ears; and in all, a muscular structure is plainly discoverable by dissection; there being a muscle for raising the ear, another for carrying it forward, and two for carrying it back.

HARRIET.

Bitter wax is, I suppose, intended to prevent insects from making their way into the tube of the ear?

DR. A.

It is designed for this purpose; as are likewise some small hairs which stand across the passage. The wax will sometimes increase to such an extent, as to occasion deafness, by plugging up the passage, and thus preventing the propagation of the vibrations of the air to the membrane of the tympanum. The obstacles to the entrance of insects are wisely intended; for the internal passage is so very sensible, as to be capable of much pain and injury in case of irritation.

HARRIET.

The undulations which you mention as occurring

in air, are somewhat similar, I suppose, to what take place in water, when put in motion.

DR. A.

Certainly; and though they are not visible, as in water, they may sometimes be felt in tremors on paper held in the hand, by the agitation of the air derived from a loud sound, which would not otherwise have affected the organ of touch.

CHARLES.

The passage of sound is, of course, very much affected by wind acting in an opposite direction.

DR. A.

Not so much as you would imagine; for the velocity of air in the strongest wind is not equal to more than the twentieth part of the velocity of sound, and cannot, therefore, under any circumstances, affect it more than in that proportion.

CHARLES.

But is the celerity of sound the same under all circumstances of strength and weather?

DR. A.

It has been found that sound travels about 1142 feet in a second, or about a mile in 4½ seconds, or 13 miles in a minute. Its velocity is the same whether it is strong or feeble; the sound of the

human voice, or the report of a cannon: but in summer, when the air is not so dense as in winter, sound travels rather more rapidly; so it does in elevated situations; while in cold foggy weather its progress is retarded. The difference in no case is, however, more than a few feet; and in a denser atmosphere, though the progress of sound is retarded, the same sounds are stronger than in thinner air. This, together with the quiet of night, appears to be the reason why sounds are heard better at this season. I may remark, however, that some late experiments in Holland, in the East Indies, and at Woolwich, make the velocity of sound rather less than what it is usually considered to be.

SOPHIA.

The knowledge of the velocity of sound will, in many instances, I suppose, inform us of the distance of a body producing it.

DR. A.

Certainly; and that very readily: for if you see a flash of lightning, or of a cannon, or discover the elevation of an arm making a stroke, you can, in any such instances, by ascertaining the number of seconds which intervene between seeing the flash and hearing the sound, by means of a stop-watch, make out the distance of the thunder-cloud, of the cannon, or of the man. A very ready

mode of accomplishing the same thing, is by an observation of the pulse, which ordinarily beats about 75 times in a minute. With a small allowance, the number of beats intervening between the light and the report, will indicate the distance with sufficient accuracy for ordinary purposes, particularly if by means of a stop-watch the rate of the pulse be ascertained. Making each pulsation as equal to 1000 feet of distance, you would be sufficiently near the truth.

HARRIET.

But is air absolutely necessary to the propagation of sound, or are there other substances which will answer the same purpose?

DR. A.

It is necessary that sound should have some material by which to be propagated; for experiments show, that in the exhausted receiver of an air-pump, sound is very much deadened, and becomes louder on re-admitting the air, though it is, of course, still a good deal diminished by the interposition of the glass. Water, however, communicates sound very well, and so does any solid body, though the readiness with which the communication takes place, is much connected with the nature of the material. Sounds which are made in water, and heard in air, are pretty much the same as if they were made in air, and heard

in water. In both cases the tone is about a fourth deepened: but the velocity with which sound passes through water has not been ascertained, though the sound of a large hand-bell, under water, was heard very distinctly and strongly, by the late Professor Robinson, of Edinburgh, when his head was plunged in water at the distance of 1200 feet.

CHARLES.

But it would be difficult to make an experiment of this kind, so as to be unequivocal in its results, because the sound from the bell would travel to the ear both by the water and the air.

DR. A.

Much care and attention must be necessary in making any experiments of this kind, and I wonder that the subject has not been prosecuted. — A piece of timber will communicate a sound from one end to the other instantaneously, or very nearly so; for experiments have been made by the union of deal rods, to a great length, and the velocity has been calculated to be more than three miles in a second. The approach of cavalry may be heard at a greater distance, when the head is in contact with the ground, than by attending to the sound communicated through the air; and waggons will often communicate a slight impulse to the furniture of a house, before we hear the noise which imme-

diately occasions it. Dr. Young tells us, that the blow of a hammer on a wall, at the upper part of a high house, is heard as if double, by a person standing near it on the ground, the first sound descending through the wall, the second through the air.

CHARLES.

I should think it not unlikely that the same might be the case in the experiment with the bell under water.

DR. A.

Not improbably; and if your law studies admitted of your being an experimentalist, this would be a good subject for a debût. — There are some substances which communicate sound better than others; for instance, a voice can be heard at a greater distance over water than land; and in a still day a whisper has occasionally been heard across the Thames. You may readily ascertain, on any long brick wall, in a quiet evening, that a very low voice or a loud whisper may be heard at the distance of between 300 and 400 feet. I have heard it at the extremities of a wall, not far from us, of above 400 feet long.

I mentioned to you, that the sound is impelled upon the membrane of the drum, which is very thin and sensible, and, through its medium, on a bony structure, contained in the cavity of the

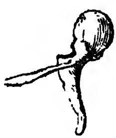
drum. This bony structure is exceedingly curious, not only in itself, but in the names of its different parts; for they are termed the malleus or hammer; the incus, or anvil; the orbicular bone; and the stapes, or stirrup.

CHARLES.

But is there any real resemblance in these bones to the things from which they are named?

DR. A.

A good deal, as you will perceive from the annexed sketches, which represent these bones considerably enlarged.



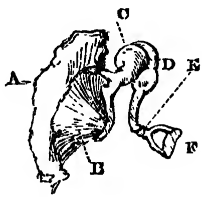
Malleus, or Hammer.

Incus, or Anvil.

Orbiculare, or Orbicular Bone

Stapes, or Stirrup.

The connection which these bones have with each other, you will be able to apprehend from another little sketch, in which A is the bony margin of the opening into the ear; B is the membrane of the tympanum; C the malleus fixed to it, and attached to the incus D; E the orbicular bone; and F the stapes.



The undulations of the air act, as I have already mentioned, on the membrane of the tympanum; this propagates an impulse to the malleus; the malleus to the incus; and the incus to the orbicular bone and the stapes. These bones are all in the drum of the ear; but the last-named, the stapes, is fixed to a membrane, covering a hole, called the oval hole; and this membrane, like that of the tympanum, conveys to the parts within, the vibrations which the latter carries to the bony structure.

CHARLES.

Then are these bones put in motion by the vibrations of the membrane of the drum?

DR. A.

It is supposed that they are; and this is exceedingly likely, as they are provided with muscles, which answer for the motions which would be produced in this line of propagation. — Connected with the drum of the ear are some little cavities in the substance of the bone, contiguous to the ear, and which are called the mastoid cells, and are supposed to have some influence in increasing sounds.

CHARLES.

You mentioned that the cavity of the drum is full of air; by what means does it obtain entrance? For, if I understand the structure of the drum right, it is totally impervious.

DR. A.

The membrane of the drum is impervious; but in its cavity is an opening, which is the termination of the Eustachian tube, a tube so called from Eustachius, its discoverer, which opens in the posterior part of the mouth. It is through this opening that the air is supplied, and fills the drum of the ear and the cells communicating with it.

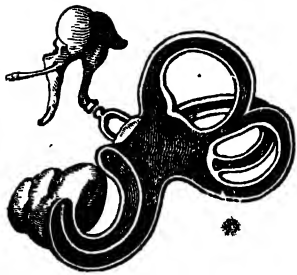
SOPHIA.

Then I dare say it is, in some degree, by this opening that hearing is assisted; for people are apt, in listening, to open their mouths, as well as direct their ears.

DR. A.

There is no doubt of this being the case; and hence we find, in sore throat, that severe pain is occasionally propagated to the ear, from this tube becoming inflamed. If it is obstructed, too, deafness is produced, because there is a difficulty in the impressions being carried on from the tympanum, in consequence of there being no yielding behind it, as is the case when the air has free ingress and egress. Hence, in such circumstances, a small opening in the drum of the ear has been found useful in restoring the proper action of the parts. Many doubts were entertained as to the propriety of making such an opening; but at last its safety was demonstrated by Sir Astley Cooper, more than twenty years ago, and the Copleian medal of the Royal Society adjudged to him for the enterprise.—The stirrup, I mentioned to you, is connected with a membrane covering the oval hole. This membrane separates the drum of the ear from another small cavity, called the vestibule; and with this vestibule, other cavities, called the semicircular canals, and the cochlea, proceed, both which, together with the vestibule, are, from their involved and irregular shape, known by the general name of labyrinth. These parts form the proper organ of hearing; for over the lining of the whole of the cavities which they form, the auditory nerve is diffused; and in

order that the impulse propagated from the drum and bones of the ear to the actual organ of sense may be as forcible as possible, the whole of these cavities are lined with a watery fluid, which is, as it accurately fills them, admirably adapted for giving effect to impressions from the bones of the ear. The various ramifications of the cavities increase, in a small space, the nervous expansion devoted to hearing; though the particular reason for the peculiar shapes of these cavities is not known. There is one point, however, worthy of notice with regard to the labyrinth; and it is this, that Nature has been so careful of losing nothing in the way of impulse, that she has made a second opening into the internal ear, from the tympanum, which is called the foramen rotundum, or round hole, and is covered with a membrane. This, it is obvious, will admit of a slight degree of movement propagated from the impulses on the membrane of the oval hole, through the medium of the fluid contained in all the cavities above mentioned, and thus the nervous expansion will be more surely acted upon. It is a matter of difficulty to comprehend this complex structure without an attentive and accurate examination of the parts themselves; but it will be rendered a little more intelligible by a sketch.



In this you will recognise the malleus, incus orbicular bone, and stapes. This last is attached, to the membrane of the oval hole, which opens into the vestibule, the central compartment of the sketch. The semicircular canals are towards the right; and the cochlea, so called from its resemblance to a snail's shell, towards the left. A small canal leads from the cochlea up to the tympanum, from which it is separated by a membrane covering the round hole. These various ramifications of the labyrinth form, therefore, the proper seat of the organ of hearing, to which the other parts are only subsidiary.

CHARLES.

I have heard of some persons who are able to puff out tobacco-smoke from their ears. I can easily understand that this must reach the ear by means of the Eustachian tube; but in what way

can it escape from the ear, since there is no opening naturally in the membrane of the tympanum?

DR. A.

Whenever this happens, it must be through an artificial opening in the tympanum, which now and then occurs in complaints of the ear. It can never take place in the healthy state of the organ.

CHARLES.

You have informed us that in one particular cause of deafness, that of obstruction in the Eustachian tube, an artificial opening made in the membrane of the tympanum will restore hearing; but I cannot understand how the destruction of this organ by disease is compatible with the continuance of the power of hearing. I should think the internal parts would be so destroyed, before it could happen, as to take away hearing altogether.

DR. A.

Not to the extent which might at first be imagined; for as long as the more internal parts of the ear are unaffected, some degree of hearing will still remain, even if some of the bones are destroyed, or come away by ulceration. This indicates that the proper organ of hearing is the labyrinth; and, indeed, in some animals there is no introductory tympanum, and no bones of the ear; but the undulations of the air are received at once

on a membrane which communicates them to the fluid, and thus to the nervous expansion of the internal ear. If however in man, or those animals which have a tympanum, the last bone of the series, the stapes or stirrup, is destroyed, the membrane filling up the oval hole will be lost also; and as the fluid contained in the inner ear will in consequence escape, deafness will ensue, from the medium being lost by which the immediate organ of hearing becomes affected. It is to be observed, however, that the bones of the head are able to communicate impressions to the organ of hearing without the medium of the air, or the aid of the external ear. Thus a watch touching the forehead is heard with great distinctness, if the ears be entirely stopt; and so is the sound of water boiling, by means of a poker touching the vessel, and taken between the teeth; or that of a tuning fork, or any other sounding body taken between the teeth.

HARRIET.

The auditory faculty must, I suppose, differ a good deal in its acuteness in different individuals, for some persons have very nice ears for music, and others can hardly distinguish one note from another.

DR. A.

There is a great deal of difference between that power of perception which constitutes hearing,

and that which is connected with the appreciation of musical sounds. The former is a faculty which is possessed by mankind very much in common; the latter varies exceedingly among different people; but it appears from some new observations of Dr. Wollaston, that some persons are insensible to various sharp sounds, as the chirp of the house-sparrow and house-cricket, the squeak of the bat, and the noise of small insects, without having any other defect in the organ.

HARRIET.

There must be very little known, then, I presume, about the circumstances which occasion a nice ear in music.

DR. A.

In that we are very much in the dark; for though Sir Everard Home has shown a muscular structure in the membrane of the tympanum, both in man and other animals, particularly the elephant, and considers this structure, by means of the different degrees of tension which it is capable of producing in the membrane, mainly conducive to the formation of a musical ear, yet as it has been ascertained, that a musical ear can be retained after the destruction of the membrane of the tympanum, this opinion is not tenable. Sir Astley Cooper observed in a case, in which the

membrane of the tympanum, in both ears, had been destroyed, that the hearing was but little affected; and that the person had an acute perception of musical sound, and sang with taste, and perfectly in tune.

HARRIET.

Do animals differ much in their powers of hearing, as it appears that they do in their faculties of vision?

DR. A.

We do not know much of the comparative acuteness in the auditory faculty in animals; but the elephant is said to be endowed with a remarkable sense of hearing, and its auditory organs are larger than in other animals, or man. Mr. Corse, who saw much of the habits of the elephant in India, and communicated some valuable information on the subject, to the Royal Society, gives some examples of their acuteness of hearing. He states that a tame elephant, which was never reconciled to have a horse moving behind him, although he expressed no uneasiness if the horse was within his view, either before or one side, could distinguish the sound of a horse's foot, at a distance, some time before any person in company heard it. This was known by his pricking up his ears, quickening his pace, and turning his head from side to side. He also mentions a tame female

elephant, which had a young one, that was occasionally sent out with other elephants, without the young one being allowed to follow. She was not in the habit of pining after it, unless she heard its voice; but frequently on the road home, when no one could distinguish any sound whatever, she pricked up her ears, and made a noise expressive of having heard its call. This having occurred frequently, attracted Mr. Corse's notice, and made him, at the time the female elephant used these expressions, stop the party, and desire the gentlemen to listen: but they were unable to hear any thing, till they had approached nearer to the place where the young one was kept.—There is a cellular structure connected with the cavity of the tympanum in the elephant and the owl, which is supposed to be in some way favorable to hearing, inasmuch as the latter, as well as the former, has acute hearing.—I may mention that the ears of fish have no external openings; and that animals which have much occasion to dive, as seals, have a valve for the purpose of closing the external ear; and this is the case likewise with owls, and with some of the more rapacious birds, the motions of which last in pouncing are exceedingly rapid.

The ears of animals offer a great variety of structure, from the existence of a mere sac, having a nervous pulp expanded upon it, up to the complicated apparatus of the mammalia, and particu-

larly of man, who, though he does not hear so acutely as some other animals, has, nevertheless, in his nice discrimination of language, and in his exquisite susceptibility to musical impressions, a perfection of the sense, which the lower animals do not possess. In the human ear there is not only the most material part of the apparatus for communicating vibrations to the internal organ, but the most extensive distribution of nerves in its inmost recesses for receiving those vibrations. There is every reason, however, to suppose, that as some small animals have microscopic eyes, and possess a power of vision far beyond what is necessary to us, or what we are capable of exercising, there is also, in many, a minute and accurate appreciation of sounds, of which we can form no idea.

CONVERSATION XIII.

OF THE ORGANS OF SENSE.

TOUCH.

DR. A.

In the account which I gave you of the integuments, I mentioned that the skin is plentifully supplied with nerves, to which it owes its peculiar sensibility. — This sensibility is diffused generally over the whole surface, and forms the principal means by which we become acquainted with many of the properties of substances, as heat, cold, hardness, softness, solidity, figure, extension, and motion. But though the SENSE OF TOUCH is diffused over the whole body, the fingers are more particularly endowed with it; and hence it is by them that we more particularly examine the qualities of external bodies.

HARRIET.

I have heard that man owes a great deal of the powers of discrimination which he enjoys in his hands, to the peculiar position and strength of his thumb.

DR. A.

I have no doubt of this being the case, for the thumb is a very important organ in the examination of the form of bodies; and though the monkey tribe, or quadrumana, have hands a good deal similar to those of man, yet their means of becoming acquainted with the properties of bodies is less complete than ours, from the thumb being weaker, shorter, and less easily brought to meet and oppose the fingers: for you may observe that it is by opposing the thumb to the fingers, that we seize and examine the most minute bodies, with the greatest accuracy. There is likewise this important difference, that we have the power of separating, and acting with the fingers separately, which monkeys have not, from wanting the particular muscles necessary for the purpose. — There are little elevations of skin called villi, from their supposed resemblance to the pile of velvet, on which the minutest ramifications of nerves and blood-vessels are diffused, so as to impart to them the utmost sensibility. This sensibility may be diminished by disease, or in some rare cases entirely lost; and though the diminution of sensibility is generally connected with a diminished power of motion, yet this is not always the case, as I have already had occasion to notice.

SOPHIA.

You mentioned that the proboscis of an elephant

and the snout of a hog are the organs of touch in those animals: I suppose that every living creature has some particular part of its body to which it owes the sensations of touch.

DR. A.

Most animals have organs of touch more or less perfect. In the ruminant animals, and horses, the lips or tongue seem to answer this purpose, as does the upper lip in the rhinoceros. The whiskers of animals of the cat-kind serve the same end, the bulbs of these hairs being largely supplied with nerves. The combs of cocks and turkeys give those animals feelings of touch; and geese, ducks, and other animals which seek their food much in mud, have their bills covered with a very sensible skin, which is supplied with an abundance of nerves. The tails of some animals have an extraordinary prehensile power, by means of which they can seize any thing as with a hand.

CHARLES.

But how imperfect must all those modes of examination be, to the nice organs possessed by the human race, by means of which our examinations into the properties of bodies are so minute and effectual.

DR. A.

For the purpose of their nature, the organs of touch in animals are sufficiently well adapt-

ed; and in particular for assisting them in their appreciation of danger, and in their search after, and discrimination of food; but the hand of man is so superior in the nicety of its formation, as well as in the acuteness and diffusion of its sense of touch, to any thing which is possessed by other animals, as to have been termed by Aristotle, the instrument of instruments; and to have been regarded by some philosophers, and in particular by Buffon and Helvetius, as one of those organs to which we are mainly indebted for our superiority over the inferior animals. Buffon carries his notions so far, as to suppose that one man may excel another in genius and ability, only because he has earlier had the unrestrained use of this sense, which the practice of swaddling in another, though carried on merely for six or seven weeks after birth, would interrupt. He also supposes, that the sagacity of animals is greater in proportion as their organs resemble those of man; and that hence the hand of the ape, and the trunk of the elephant, make these animals superior to all others. Helvetius even goes so far as to consider it not admitting of a doubt, that if nature had terminated our wrists by the hoofs of a horse, instead of flexible hands and fingers, we should have been, at this time, wandering in the forest like wild animals.

HARRIET.

What a humiliating and degrading idea! These philosophers seem entirely to put aside the intellectual part of man, that high glory and distinction, by which he is approximated in nature to the great Being to whom he owes his existence.

DR. A.

Whatever may be the nice adaptation of the parts of animals to the various functions which they have to perform; however they may even seem to exceed the human race in the perfection of some of their organs, yet man has nobler faculties than those of mere animal existence, by which he is placed at an immeasurable distance above the other races which inhabit the earth. Even if he had hoofs instead of hands, and were otherwise constituted as at present, he would still, as Mr. Dugald Stewart well observes, be man, in possession of all the faculties and powers which are characteristic of his nature, and capable by experience, and the resources of his own mind, of making up, in part, for so material a defect. — There are many examples of people born without arms, who have been able, by means of their eyes, feet, and toes, by their teeth, or by other parts of their body, to make very useful exertions, and to acquire, indeed, great expertness in various

mechanical employments. Persons have been repeatedly exhibited, who could use scissors very adroitly with their toes; and some have been described, who could discharge a pistol with them, thread a needle, write, and even comb their heads, and take off their hats. One man is living near Exeter, who is without arms or shoulders, and yet can exercise many of the duties of a farmer. He is able to lift great weights with his teeth; can catch, saddle, and bridle his horses, and do various domestic offices with his feet; and can feed, dress, and shave himself, and write with his toes. He has been twice married, has ten children, none of whom have any natural defect; and has, occasionally, battles with other men, in which he runs furiously at his adversary with his head, tripping up his heels at the same time.—But one of the most interesting examples of this kind, as you may remember, is that of a young woman, who had neither legs nor arms, and yet could sew, write, and draw.

HARRIET.

I perfectly recollect seeing her five or six years ago: her name was Beffin; and we all thought she was destitute of legs, though we were not quite certain, and did not like to make any inquiries which might be uncomfortable to her. In working with her needle, she employed her mouth, tongue,

and teeth; together with a small stump, which extended four or five inches below the shoulder; and in writing and drawing, she guided, with her mouth, her pen or pencil, which were fixed by a sort of loop to the stump of the right side.

DR. A.

In all these examples, there is a directing and an ennobling principle, of which the brute creation is destitute, and the want of which makes it preserve, age after age, the same relative position in the scale of existence. Man, therefore, is not the wisest of animals (as a great ancient physician observed), because he possesses hands, but hands are given to him because he is the wisest of animals; for it is not by his hands, but by his reason that he is instructed in the arts.

There is a very important circumstance connected with the sense of touch, which is the assistance that it gives to vision. When we consider that our perceptions of visible objects arise from a picture of such objects falling upon the retina, we know that our sense of vision merely communicates to us a picture of a certain magnitude, and of certain varieties and shades of colour. If we did not know by touch, the forms of these bodies, and were not acquainted with their particular shades, and apparent magnitudes at different distances; if we were ignorant that there were differences of shade,

answering to the different prominences and depressions of objects, the picture of the retina would merely be that of a flat, coloured, and unmeaning surface.

SOPHIA.

But are we not sensible, when we view a picture of any object, though we know that it is a flat surface, that it represents objects of various shapes and forms, and that by the different shades and different magnitudes, objects at various distances are depicted?

DR. A.

Certainly; but then we have the previous knowledge which enables us to form such conclusions. Let us take, for example, the pillar on which the dial-plate is fixed. Of what shape and size is it, what is its distance, and of what material is it constructed?

SOPHIA.

It is round, to be sure; about a foot in diameter; made of stone; and at about a dozen yards' distance.

DR. A.

The answer seems easy, but how do you come to these conclusions?

SOPHIA.

Why surely there can be no doubt of my correctness as to these points?

DR. A.

There is none as to your correctness; and no philosophy is required to communicate the information; but how do you know that it is round?

SOPHIA.

I see that the light and shade are placed in a particular manner; and even if a flat body were so painted, it would give the impression of a round one.

DR. A.

Unquestionably it would; but if you had not, by feeling the pillar in question, or other round bodies, become acquainted with what roundness is, and had not known that roundness was invariably characterised by certain shades of surface, you would have known nothing about the matter. The size you judge of by comparison with other bodies of known dimensions; that is, such as you have either touched, or compared with others which you have touched. You obtain a knowledge of distance, because distant objects are not so vivid as when near; and then their images bear certain relations, in perspective, to other bodies of known magnitude. The material, stone, you know by handling it; and when you have once seen, and touched it at the same time, the feeling of hard- coldness, roughness, or polish, as the case are immediately brought to your mind,

and give all the requisite information whenever you see the particular substance again.

SOPHIA.

Then, in fact, it would appear, that we have every information of this kind to learn: at what period does our education commence? It must begin in the nursery, for I am sure that our little Eleanor knows the shape of the pillar as well as we do.

DR. A.

Have you never observed what delight an infant takes in handling bodies which are brought near it; and as it grows in strength and intellect, how readily it recognises objects, and how correctly it recollects previous impressions? The whole of early life may be said to be a period of education, of that species of education which masters would in vain supply, which nature has placed within our own power, and which is obtained by the spontaneous exercise of our faculties.

HARRIET.

This is very wonderful, but yet very reasonable; but what would be the circumstances of a person who suddenly regained his sight (if we could suppose any such) with regard to external objects? he would have no previous means of comparing the perceptions of sight and touch, and

would therefore have to learn their relations to each other, before he could know that the white-shaded surface of the pillar related to the object which we know to be the actual body.

DR. A.

He certainly would; and I am happy in being able to communicate to you a very celebrated case from Cheselden, a distinguished surgeon, who died about 70 years since, which throws much light upon this subject. It is that of a young gentleman, who was born blind, or lost his sight so early, that he had no remembrance of ever having seen, and was couched between 13 and 14 years of age. He was never so blind as not to be able to discern day from night, and in a strong light to distinguish black, white, and scarlet; but he could not perceive the shape of any thing; nor did he know, when he was able to see, that the colours which he could distinguish in a strong light before the operation, were the same as those which he saw after it. When he first saw, he was so far from being able to judge of distances, that he thought all objects whatever touched his eyes (as he expressed it), as what he felt did his skin; and thought no objects so agreeable as those which were smooth and regular, though he could form no judgment of their shape, or guess what it was in any object that was pleasing to him.

He knew not the shape of any thing, nor any one thing from another, however different in shape or magnitude; but upon being told what things were, whose form he before knew from feeling, he would carefully observe, that he might know them again; but having too many objects to learn at once, he forgot many of them; and (as he said) at first he learned to know, and again forgot a thousand things in a day. One curious particular Mr. Cheselden mentions. Having often forgotten which was the cat and which the dog, he was ashamed to ask; but catching the cat, which he knew by feeling, he was observed to look at her steadfastly, and then, setting her down, said, "So, puss, I shall know you another time." He was very much surprised, that those things which he had liked best, did not appear most agreeable to his eyes; expecting that the persons would appear most beautiful, whom he loved most; and such things most agreeable to his sight, that were so to his taste. It was thought that he soon knew what pictures represented which were shown to him, but this was afterwards found to be a mistake; for about two months after he was couched, he suddenly discovered that they represented solid bodies, when to that time he considered them only as party-coloured planes, or surfaces diversified with variety of paint. But even then he was no less surprised, expecting the pictures would feel like the things

they represented; and he was amazed when he found those parts, which by their light and shadow appeared now round and uneven, felt only flat like the rest; and asked which was the lying sense, feeling or seeing? Scarlet he thought the most beautiful of all colours; and of others, the most gay were the most pleasing; whereas the first time he saw black, it gave him great uneasiness, yet after a little time he was reconciled to it; but some months after, seeing by accident a negro woman, he was struck with great horror at the sight. Being shown his father's picture in a locket at his mother's watch, and told what it was, he acknowledged a likeness, but was vastly surprised; asking, how it could be that a large face could be expressed in so little room; saying, it should have seemed as impossible to him, as to put a bushel of any thing into a pint.

At first he could bear but very little light, and the things which he saw, he thought extremely large; but upon seeing things larger, those first seen he conceived less, never being able to imagine any lines beyond the bounds he saw. The room he was in, he said, he knew to be but part of the house, yet he could not conceive that the whole house could look bigger. Before he was couched, he expected little advantage from seeing, worth undergoing an operation for, except reading and writing; for he said he thought he could have no

more pleasure in walking abroad, than he had in the garden, where he could do so safely and readily. And even blindness, he observed, had this advantage, that he could go any where in the dark, much better than those who can see; and after he had seen, he did not lose this quality, nor desire a light to go about the house in the night. He said every new object was a new delight; and the pleasure was so great, that he wanted words to express it; but his gratitude to his operator he could not conceal, never seeing him, for some time, without tears of joy in his eyes, and other marks of affection: and if he did not happen to come at any time when he was expected, he would be so grieved, that he could not forbear crying at his disappointment. A year after first seeing, being carried upon Epsom downs, and observing an extensive prospect, he was exceedingly delighted with it, and called it a new kind of seeing. And after being couched of his other eye, he said that objects at first appeared large to this eye, but not so large as they did at first to the other; and looking upon the same object with both eyes, he thought it looked about twice as large as with the first couched eye only, but not double, as could in any way be discovered.

HARRIET.

This is really a very important and interesting

narrative, and it serves to place, beyond a doubt, the means by which we come to a knowledge of external nature. I shall not be so anxious, in future, to prevent an infant from handling objects of its attention, since it is a species of lesson which it is giving to itself, and which is necessary to its proper education.

DR. A.

You must take care, however, that the disposition to assist its studies, is not purchased at too dear a rate; for you must recollect, that a child makes no distinction between a wooden, and a glass cup, as far as the chance of destruction goes; and that it is very long before it obtains sufficient knowledge and caution, to have all the trustworthiness of Harriets and Sophias.

CHARLES.

Have no confirmations been made of Cheselden's interesting observations, during the long period that has elapsed since his operation was performed?

DR. A.

You must observe that cases of the kind mentioned by Cheselden are very rare; for in the first place, cataract is a complaint which very often takes place after vision has been enjoyed for a long period previously; and when it has been born with

a person, the operation may have been performed before the age at which the necessary observations could be satisfactorily made. It may likewise happen, that the blindness was less complete than in Cheselden's case; and last of all, that both observer and patient may be less acute and intelligent, than is necessary for accurate observation on so difficult a subject. A similar case was described some years since by the late Mr. Ware; but as the observations made relative to it, did not altogether correspond with those of Cheselden's boy, though there was reason to suspect a greater degree of vision than in his case, and therefore a less fitness for correct deduction, some degree of doubt was thrown on Cheselden's interesting history, which for 80 years previously had been unquestioned. There has been lately published, however, by the ingenious Mr. Wardrop, in the Philosophical Transactions, the particulars of a case which agree, in the most important points, with Mr. Cheselden's narrative. In this case, a lady of 45, who was born blind, had, when about six months old, her right eye entirely destroyed by the effects of an operation which was made for her relief at Paris. An operation was likewise performed on the left eye, but without success; and it appears that owing, perhaps, in some degree to this operation, a contraction, and in time a complete obliteration of the pupil took place, with the

power of distinguishing a very bright light only. This state of things existed when Mr. Wardrop saw her; the fore part of the eye, or cornea, being transparent; but the rays being unable to penetrate into the interior of the eye, from the pupil being shut up by the iris expanding like a curtain over it. The operation necessary for her relief, was therefore to take out a small part of the centre of the iris, and thus to make an artificial opening or pupil in it, which might allow the light to pass through the eye, and be impinged upon the retina. After three operations, the sight was restored, and she found herself in possession of an entire new sense. The first object which she remarked, was a hackney-coach, when she asked what large thing it was that had passed: she was much amused with various objects which were presented to her; and enquired whether some oak-coloured doors, on the opposite side of the street, were red. She asked what a handkerchief was, which her brother threw over his face, and complained of being bewildered with the new objects, and disappointed in not distinguishing at once by the eye, objects which she could so readily discriminate from one another by feeling them.

She often asked what things were; and could form no idea what an orange was, on the chimney-piece, till she touched it. On being told that it [illegible] wine which her brother was drinking, she

said it looked to her very ugly; and when she was informed that the shining edge of a japanned tray was yellow, observed (as Cheselden's boy did of the cat), 'I shall know that again.' On being taken out of the house, she was surprised and delighted with every thing; but particularly admired the blue sky, which she said was the prettiest thing which she had yet seen, and was equally pretty every time she turned round to look at it. She was confused with the multiplicity of objects, and excited the observations of bystanders, by the manner in which she stared at every thing. Reflection of bright light was unpleasant and startling. She was sensible of the different impressions from colours, and soon learnt their different names; preferring yellow, and then pale pink. She had much difficulty in directing her eye to an object, and finding its position; moving her hand, as well as her eye, in various directions, as a person when blindfolded, or in the dark, gropes with his hands for what he wishes to touch. Sometimes when an object was held close to her eye, she would search at a distance for it; and at others, feel close to her face for a thing far removed from her. When a pencil-case and a key were put into her hands, she knew each distinctly; but on being [illegible] tell which was the one and which the other. She could distinguish large from small objects; the

upper from the lower part; saw objects erect; and could perceive motions; but on her leaving London, 42 days after the last operation, she found that she still had a great deal to learn.

CHARLES.

It is very gratifying to find Cheselden's case thus confirmed; for I have heard doubts entertained of its correctness, though the results were exactly what had been foretold would happen, under the circumstance of a person born blind, suddenly recovering his sight. Locke, I recollect, states that Mr. Molyneux, on being asked whether if a metallic cube and sphere, the shapes of which were previously known by touch, were placed before a person who suddenly regained his sight, he would know the one from the other, was of opinion that he would not, and in this Locke agreed with him. Mr. Wardrop's experiment of the pencil-case and key is quite decisive of this point. — I presume that persons who have been unfortunately deprived of vision, particularly at an early period, have their other senses, and especially their hearing, rendered much more acute, in order to make up for the defect.

DR. A.

It is wisely ordained by Providence, that there is a compensation given for most of the corporeal

defects which occur to us. We have seen this exemplified when the limbs have been wanting; and it is very strikingly so with the blind, whose hearing, power of touch, and faculty of general observation, become much more nice and accurate than in ordinary circumstances.

There are many examples on record, of blind men acquiring great facility in conducting themselves about, and in discriminating external objects. An instance is mentioned in the Manchester Memoirs, of one John Metcalf, who, though blind, was able to find his way, when the ground was covered with snow, over the most intricate roads. Singular as it may appear, he was employed as projector and surveyor of highways in difficult and mountainous parts; and was in this capacity greatly distinguished. With the assistance only of a long staff, he was able, in a way peculiar to himself, and which he could not well explain, to make his observations and designs in the most satisfactory manner.

Dr. Saunderson, formerly professor of mathematics at Cambridge, was one of the most splendid examples ever known of high acquirements in the blind. His knowledge in mathematics was very profound; and his lectures were remarkably clear and intelligible. His sensation of touch was so very acute, that he was able to distinguish, merely by running his fingers over them, between a

nuine antique and a counterfeit medal. He had a similar faculty to that which I have already mentioned on the subject of hearing, in distinguishing the distances of bodies; and he could recollect places pretty exactly, by the sounds of pavements, and the reflection of sounds from walls. He was a distinguished musician, and his ear was so nice, that he readily was said to be able to discriminate the fifth part of a note of music.

Dr. Moyes was likewise remarkable for his acquirements in Natural Science, and for his excellence as a lecturer, though he lost his sight by the small-pox in infancy. He could, from early life, use edged tools with great dexterity; and made little windmills, and even a loom. His power of discriminating sounds was exquisite, both as to the size of rooms, the number of persons which they contained, the height of those with whom he talked, and other minute particulars. He had a certain perception of very vivid rays, when refracted through a prism; and from red rays derived disagreeable sensations, which he compared to the touch of a saw; while the green were agreeable to him, and conveyed to him the same idea as that which was produced by running his hand over smooth polished surfaces. He excelled in the charms of conversation, and was happy even in his allusions to visual objects.

CHARLES.

I should imagine that the memory, in the blind, must acquire a great additional power of retention; for there must be a great many minute circumstances to recollect, in all the pursuits in which blind persons excel, of which those who see can have no idea.

DR. A.

They are cut off from all objects which distract the attention, and have, therefore, the power of making their sensations more the subject of remark, and of having them more deeply impressed on the memory, than those who see.

HARRIET.

How greatly are the blind objects of our sympathy. The countenance owes so much of its character and vivacity to the eyes, that one cannot but feel an indescribable melancholy in the contemplation of the vacant countenance, and the rolling unmeaning eye of a blind person. The beautiful and plaintive lines of Milton well depict the pensive state of mind to which the want of sight gives rise, in those who have once known its enjoyments:

"——— Thus with the year
Seasons return, but not to me returns
Day, or the sweet approach of ev'n or morn,
Or sight of vernal bloom or summer's rose,
Or flocks, or herds, or human face divine."

DR. A.

And yet there is such a charm in human intercourse, that it certainly admits of a question, to which organ we owe most of the enjoyments of life, the eye or the ear. If a person is born blind, the hearing and other organs, as we have seen, make up in a considerable degree for the defect; if he is born deaf, he is also dumb, and thus is entirely cut off from the greatest blessing of life, social intercourse, the interchange of sentiments and feelings, to which man owes so largely, his most noble and characteristic enjoyments. But what would you say to the privation of two senses, hearing and seeing?

SOPHIA.

One can hardly conceive a state of things so desolate: but have any instances of so unfortunate and pitiable a state of existence been known?

DR. A.

Condillac and Diderot have speculated on the knowledge of external objects, which could be obtained under the want of one or more of the different organs of sense; and many of their suppositions are sufficiently probable: but a case of a very extraordinary nature occurred some years since, which put some of their hypotheses to the test. It was that of a young man, named James Mitchell, the son of a clergyman in the county of

Moray, who was born not only blind, but deaf. The circumstances of this case are so peculiar and so interesting, that I shall give you the details of it at some length; referring you to the 7th vol. of the Edinburgh Philosophical Transactions for the original account *, by the very distinguished Mr. Dugald Stewart.

This poor fellow was born in 1795, is described as being athletic and robust, having an intelligent countenance, and as being one of a large family, in whom there were no corporeal defects. His mother very early discovered that he was blind, from his shewing no desire to turn his eyes to the light; and that he was deaf, from no noise, however loud, being capable of awakening him from sleep. Very early in life, he used to be much pleased with striking a key, or any thing else, which communicated a sharp sound, upon the teeth; but his principal gratification seemed to consist in sitting for an hour at a time, opposite to a small hole in the south wall of an outhouse, so as to receive, directly upon his eyes, the beams of the sun, which shone through the chink during a part of the forenoon. He was likewise pleased with the bright light of candles; and derived great amusement from concentrating the sun's rays on his eyes, by means of pieces of glass, transparent

* See also Mr. Stewart's 2d. vol. of the Philosophy of the Human Mind, and the Edinburgh Review for 1812.

pebbles, or similar substances. But though he had perceptions of light, he derived little or no assistance from his eyes, as organs of vision. His most pleasurable sensations were from taste and smell, and he eat with great voracity; but he received great pleasure also from the sense of touch, applying substances to the tongue, in order to feel their surfaces more accurately, and employing himself frequently, for many hours together, in selecting from the bed of a river, which runs within a few yards of the house, stones of a round shape, nearly of the same weight, and having a certain degree of smoothness. When visitors arrived, who were most frequently males, he discovered the circumstance by smell, and first ascertained whether the stranger wore boots: if he did, he immediately quitted the room, went into the lobby, secured, and accurately examined his whip, went to the stable, and handled the horse with much attention. If there was a carriage, he would examine the whole of it with great attention, and try carefully the elasticity of the springs. On one occasion that his d sire to visit the stable had been thwarted, he contrived to lock the servants into the kitchen, in order to be allowed to accomplish his wish.

He contrived to make known his wants by a sort of natural language. If he were hungry, he touched his mother or sisters, and pointed to the

place where the victuals were usually kept. If he wanted dry stockings, he pointed to his legs; and upon one occasion, when shoes that were too small for him were put away into a closet, he took them out of the closet, and put them on the feet of a young lad who attended him, whom they fitted exactly. When sick or feverish, he used to point to his head, or to put his mother's hand opposite to his heart. He expressed satisfaction or complacency by patting the person or object which excited this feeling; rage, by bellowing; and great pleasure by laughter. He was most readily managed by his sister, who notified her wishes to him by the different degrees of force, and different manners with which she touched his head. New clothes were his greatest delight. After his measure had been taken, every hour was full of anxiety, till the new suit was in his possession. He persecuted the tailor or shoemaker until his shoes or coat were finished, and was their guest, morning, noon, and night, till the last stitch was drawn. Tearing his clothes was the usual expression of his anger; and nothing was a greater punishment, than being obliged to wear them when torn. He obtained, by careful examination, a certain range around the house, in which he walked fearlessly, and gradually felt his way into new ground. On one occasion, he was seen creep-

ing across a narrow foot-bridge, at a place where the stream was deep and rapid: but he was prevented making any further attempts of a similar kind, by being plunged once or twice into the river, as soon as he was secured. During the cure of a wound on his foot, it was usually rested on a small footstool. More than a year afterwards, the boy with whom he used to play, met with a similar accident. As soon as he discovered this, which he did from the boy being stationary, and having bandages on his legs, he went up to a garret, sought out the little footstool, and bringing it in his hand to the kitchen, quietly placed the boy's foot upon it.

He went to church, and conducted himself reverently; but was without any appearance of religious feelings. He was attached to his family; assisted the farm servants in some of their duties, as cleaning the stable, and endeavoured to repair breaches in the farm houses, and to build houses with turf. Some attempts were made to improve his sight; but though at first promising, there was at length a complete failure. In a subsequent communication to the Royal Society of Edinburgh in 1815, by the late esteemed Dr. Gordon of Edinburgh, a few further particulars are given, and an account of some unsuccessful attempts which were made for his instruction.

SOPHIA.

You have interested us exceedingly, by the history of this poor boy, who seems so much cut off from communication with the external world; yet he has amusements and gratifications.

CHARLES.

Have no recent accounts b[illegible] him? Such a remarkable case should not be lost sight of.

DR. A.

I have been surprised that, since the account which was given of him in 1815, so long a period should have elapsed without his being noticed to the public; and it was only the other day that I was gratified by seeing, in the third volume of Mr. Stewart's Elements of the Philosophy of the Human Mind, just published, a letter from Miss Mitchell, addressed, in August last, to Sir Thomas Dick Lauder, of Relugas, in which the account of the brother was brought up to that time. — I shall mention to you the principal circumstances which are noticed in it, some of which, it appears, were stated in previous letters to the late Dr. Gordon, or Mr. Stewart, which have been mislaid. After an escape which he had from drowning, he did not for a long time visit the sea-shore; but, as his recollections became fainter, he gradually resumed his

rambles on the beach, but never entered into any of the boats.

He was once thrown down by the leaders of the mail-coach, but not hurt. Ever afterwards, however, he bolted aside whenever a carriage was approaching. He is fond of smoking, and has a regular supply of tobacco and pipes, 2 pipes and ⅓ of an ounce of tobacco per day; and never expects his allowance except at fixed times. Once he broke his pipe before the time for receiving a new one, and taking a halfpenny, which was in a cupboard, brought it and the broken pipe, with a supplicating air, to his sister; but she made signs for his replacing the halfpenny, as she knew how dangerous it was to relax, in the least degree, from the precision of her dealings with him. He was much displeased by her non-compliance; but got a present of a pipe from an out-door friend, which put him into good humour. — His mother, during her life-time, used now and then to indulge him in little things which his sister refused; and he was in the habit, therefore, of making an appeal to her, when disappointed in his applications to Miss Mitchell. He knows, however, that it is in vain to expect, now, any compliance with his capricious wishes; and if, at any time, he has asked for any thing out of the common run, (which seldom happens,) and been refused, he takes the first favour-

able opportunity of getting over his displeasure, and becoming friends with his sister again.

For some time after the loss of his mother, he seemed to experience the fear of losing his sister also; and when at any time she got away from home, he instantly went round every part of the house in quest of her. He is continually anxious to secure her personal services, and will wait till a servant is out of the way, to get his pipe lighted, or have any other little office performed by her; and in case of his sister's absence, will reserve all his little repairs till her return. He walks about fearlessly in all directions, many miles from home; is much amused with the various occupations of work-men in Nairn, the town where he now lives; and will climb ladders, and mount scaffolding without dread, and hitherto has done so without [illegible]. He makes himself at home every-where, and is so inoffensive, that he is allowed to enter [illegible], and handle every thing at pleasure. [illegible] classes seem to contribute to his safety and amusement; and only on one occasion did he ever meet with a rebuff, and that was at a house which was occu-pied by strangers, who were quite unacquainted with his situation. He was [illegible] the family thought, handling the [illegible] the lobby; and as they got no [illegible] strances on the subject [illegible] by the shoulders, not without [illegible] however, for

he gave them all the kicks and blows in his power. He was terribly annoyed at this incident, and was seen, just after the occurrence, by two gentlemen, bellowing with rage, and not to be pacified.—He does not now like the confinement of church, and though he accompanies his sister a little way on the road, he gently declines carrying the bible, which he used to do when he wished to accompany her.

CHARLES.

How much the poor fellow is indebted to the kindness of his sister, for a great deal of the little enjoyment of which he is capable. It is quite delightful to see how she devotes herself to his service; he may be said to exist in her sympathy and attachment.

DR. A.

Sir James Macintosh had a long interview with them some years since; and in a letter to Mr. Stewart, feelingly, and elegantly observed of Miss Mitchell, that the habitual exercise of ingenious benevolence seemed to him to leave its traces on her naturally agreeable features, and to give an expression more delightful than beauty.

CHARLES.

I cannot conceive in what way the poor fellow can so readily find his way about the country in all directions. He is not described as using a

stick, or feeling his way; and yet it must be by the acuteness of his sensations of touch, that he is principally guided, as he is destitute of any assistance from hearing. He is represented as at first having laboriously explored a small space around the house, which he then walked over fearlessly; but now he seems to be able to go many miles from home without preparation.

This particular point does not appear to have attracted sufficient attention. Smell may have some effect in assisting him; but touch, I should imagine, is the principal agent. I hope, however, that his amiable sister, or some of his discerning friends, will direct their particular observation to his mode of appreciating the positions of places, and those inequalities of surface which he must continually meet with. In the instance in which he turned aside at the approach of a carriage, it is clear that the vibration from the earth must have been communicated very sensibly to his body, and given him warning of the object which he wished to avoid.

HARRIET.

The want of one sense is an essential privation, though it is often made up by the greater perfection of those which remain; but that of two seems

to shut out almost every avenue to comfort and enjoyment.

DR. A.

But if you supposed a person, in addition, born without the sense of touch, he would, it is clear, have no conception of the shape, or of any other of the external characters of bodies, any more than of their visual appearance. Imagine, likewise, the sense of smell deficient, by which he could ascertain the neighbourhood of certain bodies, giving out certain exhalations; and the power of distinguishing, by taste, the flavour of any thing received as aliment, you would leave to him hardly an avenue of connection with the world in which we live. Man, therefore, from the earliest period of life, imperceptibly becomes acquainted with external nature; and by the proper employment of his corporeal functions on the one hand, and of his mental faculties on the other, he acquires an elevation to that high rank in the creation, which Providence has assigned to him.

SOPHIA.

Have the lower animals any means of compensation for defective organs, as is the case with man?

DR. A.

It is not improbable that this may go to a certain extent; but on this it is exceedingly

difficult to form an estimate. It cannot go far, however, for it is in a great degree by the powers of reasoning, co-operating with the senses, that man is able to make up for any deficiency which he may have, either by accident or nature; and you have seen this remarkably evinced in the proficiency which various persons have made in mechanical arts, notwithstanding the want of hands.

CHARLES.

And yet there seems to be a faculty in animals, which approximates to reason in man; for when a well practised horse measures the height of his leap, and will not attempt what exceeds his force and ability; and while an old grey hound leaves the fatiguing part of the run to the younger, and places himself so as to meet the hare in its doubles, it cannot be denied that they enjoy a reasoning faculty, to a certain extent.

DR. A.

Animals unquestionably possess the powers of external perception and memory, and they likewise exhibit judgment, which is strikingly exemplified in the instances which you have given; and some of them are remarkable for the attachment which they have to individuals of the human race. In these circumstances they resemble man; but without going into metaphysical subtleties, their great discriminating characteristic seems to be

the strength of instinct, by which they are instructed by nature in all that is necessary to their existence, while man requires experience, and is largely endowed with the faculties by which he can gain it.

SOPHIA.

It is curious that animals should come more perfect, if one may so term it, out of the hands of their Maker, than man himself.

DR. A.

But this is an acknowledgment of the higher faculties which man possesses, and which give him the means of obtaining knowledge and experience for himself. — Young partridges and grouse, when they come from their shells, are able to move about among corn, grass, or heath, without the apparent necessity of any experience as to the distances of what may be injurious, or not. Chickens, as soon as they are hatched, can run about in all directions, and can make their way in a straight line to grains of corn, even at the distance of several yards, while man has to gain accuracy of vision by long experience. In the early periods of the history of society, the lord of the creation was obliged to be contented with a rude hut, or a natural excavation for his habitation; but the bee could build its cells with all the mathematical precision of which it is now capable, the bird its nest,

and the beaver its subterranean dwellings, at the first creation of the animal, as well as at present. One of our greatest poets, makes man the imitator of animals, when he says,

> " Thy arts of building from the bee receive,
> Learn of the mole to plough, the worm to weave,
> Learn of the little nautilus to sail,
> Spread the thin oar and catch the driving gale."

Instances of instinct are numberless in the animal creation. — There is a wonderful example of instinct in the migration of birds, which find their way over unknown regions by the unerring guidance of nature. The same is likewise the case in the ascent of fish up almost insurmountable obstacles, to deposit their spawn in secure places; and in the position which insects select for their eggs, for the purpose of insuring proper nourishment to the young, as soon as they require it; and in short, there are none among the infinitely numerous races of animals which inhabit the earth, that do not afford beautiful examples of that instinct, to which, in so material a degree, they owe their existence and their support. Of certain variations in the application of their instinctive powers, animals are capable; and Huber's delightful works on bees and ants, and Kirby and Spence's Entomology, contain many examples of this kind; but still these powers are complete at first, and depend in no degree, as in man, on the operations of experience.

HARRIET.

It is pleasing, in contemplating animals, to consider them as having discrimination and intelligence. The dog, which is our companion, and the horse, which contributes in so many ways to our gratification, would not be half so interesting and amiable, if we did not consider them capable of attachment, and having something of our own feelings in them.

DR. A.

There is an interesting anecdote, mentioned by Holcroft in his Memoirs, of the attachment which race horses sometimes have to the boys who take care of them. These boys (and Holcroft was early in life one of them), sometimes fall asleep in the stalls, from fatigue; and in such cases, the horses will not lie down for fear of injuring them; and you know that our old chesnut is so fond of the stable cat, that he will take her up in his mouth without hurting her; and she is continually lying upon his back as a place of ease and comfort.

CHARLES.

What do you think of Locke's story of the speaking parrot, or rather Sir William Temple's, as quoted by Locke?

DR. A.

at the parrot was certainly a very conversable

animal, and much cleverer than either Leibnitz's dog, or the most learned of the learned pigs.

SOPHIA.

I should be curious to hear something of this extraordinary animal.

CHARLES.

It was a parrot which Prince Maurice saw at Brazil 150 years ago, that spoke, and asked, and answered common questions like a reasonable creature. The prince conversed by means of an interpreter, as the parrot could only speak Brazilian. The prince asked him at his celebrated interview, where he came from. He answered, "From Marinnan." "Who do you belong to?" "To a Portugueze." "What do you do there?" "I look after the chickens." The prince laughed, and said, "You look after the chickens?" "Yes, and I know very well how to do it;" making a chuckle four or five times, as people do who call poultry to them. The prince's chaplain, who was present, could never bear the sight of a parrot afterwards, for he thought they all had a devil in them.

HARRIET.

And what was the story of Leibnitz's dog?

DR. A.

This was an animal that was taught all the letters of the alphabet except m, n, and [illegible]; and would

repeat them, and about thirty words, including Thé, Caffé, Chocolat, Assemblée, after his master, a German peasant, who had employed several years in giving him these accomplishments. It is difficult to conceive, however, that the organs of a dog could admit of such appropriation; and Mr. Steward is therefore of opinion, that it was by means of a species of ventriloquism on the part of the master, that the public, and Leibnitz among the rest, were imposed upon in this instance.

It has been said that monkeys, when they have lost their teeth, have learnt to crack nuts with a stone; and an elephant at Exeter 'Change, when a shilling was placed near a partition, but beyond the reach of the animal's trunk, blew hard against the partition, so as to bring the shilling within its grasp. You have all heard of the monkey that made use of the cat's paw to reach the roasting chesnuts; and a story is told by a French philosopher, of a monkey that was chained so as not to be able to reach some nuts of which it was very fond, that snatched a napkin from a servant who was passing, and made use of it to draw the nuts to him. He broke them by letting a stone fall on them; and once when the weather was wet, and the nuts sunk into the ground, he accomplished his purpose by placing a tile under them.

Notwithstanding, however, the sagacity which has been exhibited by various animals, the faci-

lity with which they may occasionally be taught, and the power of accommodation which they can sometimes exercise, yet the most sagacious of them, the monkey, has never been known to keep up a fire, the warmth of which it enjoyed, by throwing a faggot upon it; nor the dog, though the witness and partaker of our cookery, to broil a single portion of raw meat.

CONVERSATION XIV.

OF THE PREPARATION OF THE FOOD.

DR. A.

It is now my intention to give you some information with regard to the mode in which the animal body is nourished, and you will find that a very extended and important system of organs is devoted to this object. The functions of circulation and of respiration, I may observe to you, are carried on by means of organs situated in a cavity, which is called the chest, or thorax; and those which are concerned in the preparation of the food, and in nutrition, in a cavity beneath, called the cavity of the abdomen. The chest is occupied principally by the heart, and the lungs; the abdomen by the stomach, the intestines, the liver, the spleen, and the pancreas or sweetbread. These two cavities, or bags, are separated by a partition called the diaphragm, or midriff, which is partly of a fleshy, and partly of a membranous nature, and readily gives way, by its laxity, to the alternate ex-

pansion and contraction of the chest in the action of breathing, to which its muscular power eminently contributes. The STOMACH is the first of the organs connected with digestion; but previously to saying any thing of its nature or functions, it is necessary to state to you how the food is prepared for being taken into it. The stomach is connected with the mouth by means of a long tube, which is called the œsophagus, or gullet, and receives the food from the mouth; but the first action to which the food is subject is mastication, or chewing, and for this purpose, man, and most other animals, are provided with TEETH, which differ in their nature according to the habits of the animal, and the particular description of food which is intended to nourish it. The subject of the teeth requires particular elucidation, and will form the business of our present meeting.

SOPHIA.

But have all animals not teeth? I should have thought, that the dividing of food, which is requisite with us, would be equally so with other animals.

DR. A.

With other animals using the same kind of food it is so; but then we shall see that when nature has not given teeth fit for grinding, she has other resources in the stomach itself, for that sort

of preparation which it is necessary that the food should undergo, previous to digestion. Birds, for example, have not teeth: and with various other animals, as fish and serpents, the teeth seem to be only adapted to prevent prey from escaping, which is swallowed whole.

SOPHIA.

I cannot conceive how an animal, swallowed whole, can ever become adapted to nourish; for with us digestion would be impeded, I should think, if we were not to employ our teeth.

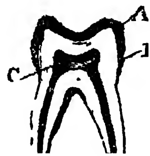
DR. A.

And yet you may have heard of *bolting*, which is employed in some parts of England, especially when the more rancid and fat meat is employed. To bolt bacon, it is said, is one of the requisites of a farmer's servant in Yorkshire. I have already, however, mentioned, that the power exercised by the stomach, is connected with the greater or less preparation which the animal is able to give to the food previous to its introduction; and of this I shall have occasion to give you examples, when on the subject of digestion.—The nature of the teeth depends on the nature of the food which the animal is intended to employ; namely, whether it is animal, vegetable, or of a mixed nature. Animals which live upon animal food are called car-

nivorous; those which live upon vegetable food are called graminivorous; and those which live on both, or either, are omnivorous, a term exceedingly well adapted to man, who is to be reckoned among the most luxurious of this class. By the inspection of the teeth, we are therefore able to form an opinion as to some of the most material habits of an animal.—The teeth which first exhibit themselves are called milk, deciduous, or temporary, from their being intended to continue only a few years, and then to be parted with. Those which supply their places when they are shed, or which appear later, and are not shed at all, are termed permanent.

The teeth in man are composed of two parts; a bony, which constitutes the body of the tooth, and is in nature very similar to real bone; and a bright, smooth, thin external covering, called the enamel. The part which is out of the jaw is called the crown and neck; while the fangs, or roots, are planted deep in the jaw. There is a small cavity in the body of the tooth, which descends in the form of a small tube into the fangs, and contains the vessels and nerves which were employed in the original formation, and subsequently in the nutrition of the tooth. In the vertical section which I now show you of a tooth with two roots, A is intended to represent the enamel of the tooth; B the bony part, or body; and C the cavity,

extending into the fangs, and apparent in a small hole at the points of each.



SOPHIA.

But is not this the mode on which all teeth are formed?

DR. A.

The other omnivorous animals have teeth of a similar structure; and such is likewise the case with the carnivorous; but in the graminivorous, the enamel descends into the body of the tooth, and by forming several perpendicular layers, enables the tooth to resist, much more than it would do if made of bone merely covered with enamel, the attrition necessary in mastication; for the enamel would soon be worn off, and then there would only be the softer substance of the tooth remaining.

CHARLES.

I see that we are able to distinguish between the teeth of the graminivorous animal, and those of the other two descriptions, by the enamel cover-

ing the teeth, or descending into the body of them; but are there differences likewise between those of the carnivorous and the omnivorous animals?

DR. A.

In carnivorous animals, the teeth all fit into each other very nicely, when brought into contact; whereas, in the omnivorous, there is a certain latitude of motion admitted, for the operation of grinding the food.—The *temporary* teeth, in the human race, are 20 in number, and are divided into three kinds; the front, incisores, or cutting teeth, of which there are 8, namely, 4 in each jaw; the canine teeth, dog teeth, or cuspidati, which are 4 in number, one on each side of the incisores, and are of a pointed or conical form; and the grinders or molares, from mola, a mill, which amount to 8, being 2 back teeth, above and below, on each side. The *permanent* teeth are 32 in number. There are, as in the temporary, 8 incisores, and 4 cuspidati; 2 bicuspidati, or two-pointed, next to the cuspidati on each side, amounting to 8; and 3 molares on each side, above and below, making 12, of which the 4 hindermost are denominated dentes sapientiæ, or teeth of wisdom, from their not appearing till adult age.

HARRIET.

But how does it happen that there is occasion

for two sets of teeth; and that the number which we have in the second set is greater than that of the first? I thought that where a tooth was shed, we merely gained another in its place.

DR. A.

There is a very great disproportion between the magnitude of the jaw in the young and adult: and as the teeth, from their nature and mode of growth, do not admit of any increase of size, it was necessary, when the jaw became larger, that a supply of larger teeth should be given. Hence a second set was afforded. But still this was not sufficient for filling up the lengthened jaw; and as youth advanced, some teeth were therefore provided far back, which did not exist in early life; the last supply of which, in the wisdom teeth, does not, as I have already stated to you, take place till adult age, some time after all growth in the jaws has terminated.

CHARLES.

I should be very curious to know from you, the particular periods at which we obtain, lose, and regain our various teeth; for I presume there is an established law of nature with regard to all those processes.

DR. A.

When about seven months old, a child gets the two first lower front or incisor teeth; and in a few

weeks subsequently, the two corresponding upper ones. After a lapse of a few weeks more, the lateral incisors appear, sometimes the lower first, and sometimes the upper. Within the first year, a child therefore gets eight teeth, four below, and four above. At the end of the first year, or beginning of the second, the first grinder appears on each side above and below; and not till some time afterwards do the canine teeth show themselves, though they are next to the incisors, and might be expected to follow them. About the end of the second year, or beginning of the third, the second grinder on each side, above and below, emerge from the gum, and this completes the 20 first or deciduous teeth which we possess.

About the age of six or seven, the two lower incisors are shed; and then follow, after some time, the two upper, whose places are supplied by permanent teeth, which soon appear above the gum. The lateral incisors are next displaced, which are renewed in a similar way: then the temporary molares, and last of all the canine, about the age of eight or nine, which are supplied at irregular periods afterwards. But in the mean time, the first permanent grinder has shown itself about the seventh year; and in the renewal of the deciduous teeth, the permanent follow the shapes and designation of those which they succeed, with the exception of the two temporary molares, which have

the two permanent bicuspid or two pointed substituted for them; the last of which, however, does not appear till the 10th or 11th year. By that time, or a little subsequently, therefore, the child has a renewal of all the 20 deciduous teeth; and to these have been added, as I have already mentioned, about the seventh year, the first permanent grinder. The second permanent grinder does not follow till about the 12th or 14th year, and the wisdom teeth complete the number, about the 20th or 21st year, and after the jaw has acquired its full magnitude. It must be observed, however, that there are many varieties in the particular order and period at which teeth either shed themselves originally, or are shed or renewed.

CHARLES.

It appears, therefore, that when that part of the jaw which contains the temporary teeth becomes too large for them, other teeth are supplied of a larger description, which are permanent; that the back part of the jaw, which originally had no teeth in it, becomes lengthened with the increase of years; and that in order to supply the vacant space which such increase of length would occasion, new teeth are afforded in proportion to the increased length which the jaw obtains; and that finally the space is filled up by the tooth of wisdom, when the full length has been obtained.

DR. A.

This is precisely the case; and we shall find, when I mention to you the mode in which the formation of the teeth takes place, that this plan is admirably adapted to the object in view. The carnivorous and omnivorous animals have teeth of a similar kind; but it is to be observed, that many of the carnivorous animals are beasts of prey, and that their teeth are part of their natural weapons of attack. The tusks or canine teeth, are, in such animals, and indeed in some others, as the hog, very formidable instruments of offence; and, when conjoined with the sharpness and strength of the claws, they render many animals of the cat kind, as lions, tigers, leopards, &c., very terrific foes.

SOPHIA.

The graminivorous animals seem to have the peculiarity of teeth which you mention as belonging to them, in order the better to fit them for using that kind of food which is intended for them, and which requires a great deal of grinding; but their front teeth, I should imagine, like ours, are solely intended for cutting, and, therefore, do not require any particular extra provision.

DR. A.

The front teeth, or incisors, have not usually

occasion for that peculiar structure, in graminivorous animals; and nature has only therefore imparted it to the teeth required for grinding. Cattle and sheep, whose front teeth are confined to biting the grass, have them sharp, and the enamel of these teeth covers their outside only, as in man; but neither cattle nor sheep have incisors in the upper jaw. In horses, where both the front teeth and the molares are employed as grinders, the enamel is distributed through the body of the tooth, in both descriptions of teeth, in the way which I have described as belonging to graminivorous animals.

CHARLES.

One observes, in looking into a horse's mouth, that the division into two substances is distinctly seen; and, I suppose, that a horse loses what is called the mark of mouth when a certain quantity of attrition has rubbed down a part of the mixed substance, so as to take off the appearance of cavity in the front teeth.

DR. A.

This is the case, for the enamel in the front teeth descends but a short way into the body of the tooth; and horse-dealers sometimes attempt to give an appearance of such cavity in the head of a tooth, by means of an engraving tool, and the communication of a black colour by a hot iron. This is what is called bishoping.

CHARLES.

I wish that I knew a little more about the marks of mouth in a horse; and, perhaps, you can give me some information on this subject, which I hope the girls will excuse.

DR. A.

I think I am enough of a jockey to tell you all that is principally worth knowing on the subject. It is not alone by the marks on the teeth of horses that their ages are judged of, but by the number and description of the teeth which they possess; and which, in cattle and sheep, likewise afford to graziers the means of determining the ages of those animals. The horse has forty teeth, viz. 12 front teeth, six above, and six below, which are called incisors or nippers; twenty form molares or grinders, six on each side, above and below: to which are to be added, four canine teeth or tushes, one above and one below on each side, which are generally wanting in the mare. From 2½ years old to three, a horse sheds the two middle teeth of the lower jaw, and the corresponding teeth of the upper. From 3½ years old to four, he sheds the two next in both jaws. From 4½ to five, he sheds the two outermost front teeth in each jaw; and at the same time the canine teeth, or tushes, make their appearance. From five years old to seven, the age is judged of by the appear-

ance of the cavity in the front teeth, as you have already noticed. The two middle lower teeth, which are lost first, and are, therefore, removed earliest, have this cavity soonest worn down; and at five years old, the black marks in them have nearly disappeared. At six the same has happened to the two next teeth; and from seven to eight years old, the marks in the two corner teeth are worn down, so that all power of discriminating the age of a horse, as far as the lower front teeth are concerned, is lost. At the same time the tushes alter their shape, and become round, or convex next to the tongue, instead of being concave. After the age of eight, we look to the upper teeth, and to some other circumstances, for judging of the age of horses; for the upper teeth are not worn down so soon as the lower. At eight, the cavities of the two middle upper teeth disappear; at 10, those of the two next; and at 12, those of the corner, or outermost. Aged horses lose the transverse ridges which are so prominent on the roof of the mouth of the young, and which gradually become flatter and more level, as they advance in life. The eyes likewise become more sunken, the eyelids lean and wrinkled, and the cavity above the eye more hollow. Grey hairs shoot out upon the forehead, and lower part of the mouth; the lips become lean and shriveled; the lower lip hangs much below the upper; and the ears drop laterally.

CHARLES.

Are there no means of discovering the deception which dealers practise on the teeth of horses, to make them appear within mark of mouth?

DR. A.

A little observation will enable a person to detect the fraud; for in a young horse the front teeth meet perpendicularly; while, as he grows older, the teeth take a more horizontal direction; the upper teeth projecting over the lower ones, and the upper corner tooth forming a curve over the lower corner tooth. Furrows likewise appear on their front surface, and their colour becomes yellow and opake.—As a horse at five years old is more saleable than one at four, attempts are sometimes made to give a horse of four, the appearance of being five, by drawing the outer front teeth in each jaw, in order to protrude the new teeth prematurely. It may, however, always be known that a horse has not attained his fifth year, if the corner teeth, above and below, are not complete in their size and appearance, and the marks of the middle teeth do not begin to be obliterated.

CHARLES.

I suppose the direction of the enamel in the teeth of graminivorous animals, or the numbers of layers, is not material?

DR. A.

It does not appear to be so; but yet there is a great similarity in the distribution of this substance, in the same genera of animals, as indicated by a similar waved appearance which it exhibits on a horizontal section.—There is a very curious difference in the disposition of the enamel in the African and Asiatic elephant, which is worth your notice and recollection. In the African, it is always in the form of transverse lozenges, which touch each other in the middle of the tooth; in the Asiatic, in the form of transverse flattened ovals; and this difference is so constant, that you may always know, by a slight inspection, whether the tooth has belonged to the one or the other of these species.

SOPHIA.

But is not ivory the product of elephants' teeth? The substance is uniform, and does not present the differences which you mention.

DR. A.

The ivory is furnished by the tusks, and not the teeth; and these former are planted in the upper jaw, and are of the largest size in male elephants.

CHARLES.

I recollect once seeing a ball in the tusk of an elephant. It obtained its position, I suppose,

during the growth of the tusk, and while its ossific matter was not sufficiently consolidated.

DR. A.

Certainly, for a ball might afterwards break, or otherwise injure, but could not enter into a firm tusk.

HARRIET.

One would suppose, from the appearance of teeth, that they were an insensible mass; and yet they must be plentifully supplied with nerves, as there is so much suffering in them.

DR. A.

They are destined to be terrible plagues to mankind; for they are obtained with suffering in infancy, and are frequently productive of great distress in after life; and though they exhibit no particular sensibility in ordinary circumstances, yet, when the substance of the tooth becomes decayed, and in particular when the nerve becomes by this means exposed to the air, intolerable pain is produced.

HARRIET.

I have often wished that the teeth were totally insensible; and, indeed, I do not exactly see why so extreme a sensibility should be given to parts, which are merely intended to act as solid bodies.

DR. A.

You must recollect what I remarked relative to the structure and growth of bones, in order to be convinced that an organisation of nerve and blood-vessel is necessary for their production, as well as for preserving them in health. The same is the case with the teeth; but the vitality of the latter, if we may so term it, does not seem to be so active as that of ordinary bone, which possesses, as I have already explained to you, a principle of reparation of which the teeth are destitute. The formation of the teeth is an example of an interesting process in the animal economy, very analogous to the formation of bone. Before the jaw is thoroughly ossified, several little bags, or membranes, are discoverable in it, which adhere firmly to the gum, and are supplied liberally with blood-vessels. Into these little bags, the blood-vessels throw a portion of pulp, or jelly, which is intended to form the future tooth. At first there are no sockets, but the edge of the jaw shoots out bony fibres, which form them. Bony matter, in time, is thrown out on different parts of this pulp, generally answering to the number of prominences, and forming either one, or several small elastic shells, which gradually unite, so as to produce one solid mass. An elongation of pulp forms the material for the formation of the roots; and in proportion as this deposition, and its ossifi-

cation takes place, the body of the tooth rises in the socket, till, by pressure on the gum, it wastes it, and the tooth begins to appear in the mouth.

SOPHIA.

So that, in fact, it is by the growth of the part beneath that the tooth is forced up; but does the membrane rise up with it, for I never heard of a tooth being covered with a membrane?

DR. A.

As soon as the body of the tooth is formed, there is no further occasion for a secretion of bony matter from the upper part of the membrane; for you will observe, that in the lower part, or the roots of the tooth, the membrane is carrying on its secreting operation, long after it has ceased to do so above. As soon, therefore, as the ossific process is completed in the body of the tooth, the membrane changes the nature of its secretion, and covers all that portion which is intended to be exposed, with a soft and moist deposit, which gradually hardens, and forms the firm and indestructable substance called the enamel. The investing membrane having thus completed its function, is wasted, and separates: but it remains permanently attached to the roots of the tooth, and when inflamed, gives the sensation of the tooth being elongated.

HARRIET.

Our first teeth last us only a certain time; they seem to decay away at their roots; and nature appears to have anticipated this, by forming a second set for the purpose of supplying them.

DR. A.

You will find that this decay is only a disappearance; and that the two processes of forming the new tooth, and removing the old one, go on at the same time.

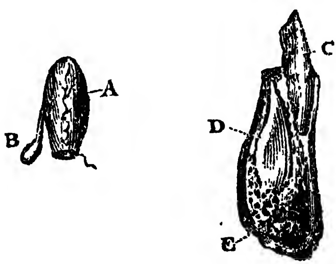
SOPHIA.

I cannot understand how this can be the case.

DR. A.

When the rudiments of the temporary teeth are pretty far advanced, the upper part of the original membrane sends off a new sac, or bag, to the place of deposit for the pulp of the new tooth. As the temporary teeth rise, the membrane which joins the two sets is elongated, and in time the new one gets a socket of its own. The process of deposition of pulp; its ossification in various parts, answering to the future prominences; and the secretion of enamel, go on, in succession, in order to prepare the second set for taking a permanent place as successors to the first. The continual accession made to the roots forces up the body of the tooth, which, pressing against the socket, and

then against the roots of the first set, produces an absorption or disappearance of them; till, in time, the old tooth, being held only by the gum, drops out with a very little force. In the sketch which I now show you, A represents the sac containing the milk, or temporary tooth; B the sac of the permanent tooth attached to the sac of the milk tooth; C an incisor tooth above the gum, with its root unabsorbed, and a vacant space at its side, from which another incisor has fallen; D a permanent tooth, rising up to supply the place of the temporary one which has been lost; E the spongy part of the jaw.



SOPHIA.

But in what way can mere pressure produce the disappearance or absorption of the roots of the teeth?

DR. A.

This is a very usual effect of pressure, and by no means a solitary example in the animal economy, as I mentioned when we were on the subject of the bones. Tumours, for instance, which grow slowly, and particularly that species which is called aneurism, will, by continued and increasing pressure, often produce a gradual disappearance of contiguous bones; such, for example, as the breast bone, when the aneurism happens to lie in the chest, and immediately under it.

HARRIET.

But we sometimes observe that people have very irregular teeth, and that the new ones have not grown exactly below the others: would this process of absorption be interrupted in such a case, and should we find the old ones with roots, instead of being half eaten away, as they appear to be when they quit the gum?

DR. A.

Under such circumstances it is often prudent to extract the old tooth, in order to make room for the new one; and then the root is frequently found either whole, or partially only absorbed; because the necessary pressure against it had either been wholly, or in part wanting.

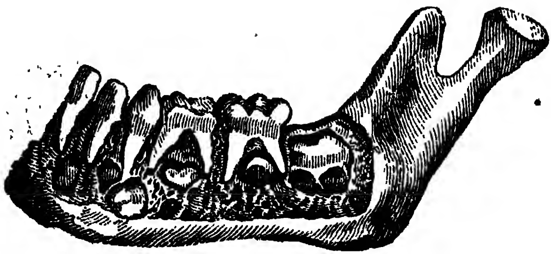
SOPHIA.

This is really a very beautiful provision of nature: but it is a great pity that there is not a greater provision of those useful little bags of pulp, by means of which the teeth might be restored after they are lost.

DR. A.

Perhaps you might likewise wish, that nature had dispensed to mankind a longer protraction of existence, and thus altered her original designs. It does happen, however, that in some very rare instances, old people have unexpectedly got new teeth in advanced life, which must have arisen from an additional sac having originally existed, or been formed under peculiar circumstances.

In another sketch, you will see the appearance of one side of the lower jaw, when all the five temporary teeth have arisen above the gum; and below these teeth you may observe the permanent ones, which are preparing to supply their places. A permanent molaris is far advanced, and is ready to take its position among the other teeth; and the other molares, as I have already stated, appear in succession, up to the wisdom-tooth, in proportion as the jaw becomes sufficiently elongated to receive them.



HARRIET.

You mentioned the shedding of teeth in horses, cattle, and sheep; and I suppose the same circumstance takes place in other animals.

DR. A.

In most animals a part of the teeth is shed, and for the same reason as in man; namely, that the original ones, which are adapted to a small jaw, will not do for a large one; and as the teeth cannot grow, after they are fully formed, a new set became necessary for the enlarged space which they were to fill.

CHARLES.

The circumstances which you describe, as attaching to the formation of the teeth in man, apply of course to other animals; but I am curious to how the enamel is diffused through the body tooth in graminivorous animals.

DR. A.

Animals of this kind have, like the carnivorous and omnivorous, a membrane, or sac, in which the pulpy matter is lodged; but this membrane, instead of merely surrounding the pulp, doubles down into it, in several places, and thus divides it into several portions, or compartments. When ossification is completed in each of those portions, the membrane assumes its new office of secreting enamel, which it deposits against the perpendicular masses of bone. A very little consideration will show you, that when once the upper surface is worn off, an appearance of alternate layers of bone and enamel will be produced. But, in this case, it will be seen, that a small vacuity is apt to be left between each pillar of ossified substance. When this occurs, it is either filled up with portions of food, as is frequently the case in the ox or sheep, or with sand or clay; or the membrane itself, or an external layer of it, secretes a sort of substance, intermediate between bone and enamel, which supplies the whole of the interstice. This has been called the *petrous crust*, and occurs in almost all the graminivorous class of quadrupeds. It does not exist in the incisors of the horse, and hence the appearance of the cavity, which, till it is worn away, affords the means of determining his age.

SOPHIA.

Then, in fact, we may conceive the enamel to dip down and return in a tooth, very much like the finger of a glove over the fingers?

DR. A.

Very much so; and if two or three fingers of a hand, with a glove on, are placed together, they may represent the grinding teeth, before they are worn by mastication. If you cut off the ends of the glove, and leave the fingers exposed, the fingers may then, in a rough way, designate the bony part of the tooth, and the glove between them, the enamel descending into its substance. The enamel between the different processes of the tooth will be double, just as the glove is, between two particular fingers; and between the doublings, either the petrous crust, which I have mentioned, or portions of extraneous matter, may obviously be admitted. —There is a very curious circumstance which I must notice to you relative to the teeth of the elephant. In this animal, the enamel, as I have already observed to you, descends into the body of the tooth; but the grinders are so soon destroyed by attrition, as to require a means of renewal which does not attach to the other descriptions of graminivorous teeth. The jaws of the elephant [illegible]urnished with one large mass of tooth, hard [illegible] the front and exposed part, and soft and pulpy

behind. As soon as mastication has rubbed away the front portion, the hinder is pushed forward by the formation of pulp, and conversion of it into ossific matter, at the same time that the fangs of the part whose body is rubbed away are absorbed, in order to make way for the protrusion of the part behind. The elephant's teeth are, therefore, in a continual state of destruction and renewal.

CHARLES.

How very admirable are the resources of nature for the protection and comfort of animal life. I could not have imagined, till you favoured us with these details, that teeth could afford so much opportunity for the exhibition of beautiful design and admirable adaptation; but is such a process of renewal frequent among animals?

DR. A.

Not very frequent. A similar structure, however, has been discovered in the Ethiopian hog; but in the shark, whose teeth are spear-shaped and very sharp, notched at the edges, and covered with enamel, several ranges of them are formed, and continually forming in the jaw, to supply such as are broken or torn away. The same is the case in a species of skate, which has teeth of a similar kind, and is apt to have them injured, by breaking the shells of lobsters, crabs, &c. which form its chief food.

There is also a singular power of renewal in the teeth of venomous serpents. These animals are distinguished by having a sharp, hollow tooth, or fang, in the upper jaw, on each side, the base of which communicates with a poison-gland situated below the eye. This tooth, in ordinary circumstances, lies flat; but it is capable of being erected; and then, either on biting, or, as has been lately supposed, by the action of the same muscles which erect it, the poison-gland is pressed upon, and a minute portion of the poison forced through the hole of the tooth into the wound. The poison-fang is very apt to get entangled and broken; but there is a provision for its supply in the germs of future fangs, which exist as pulp in little bags in the jaws; the new fang becoming ossified, and advancing forward to take the place, and assume the office of the old one.

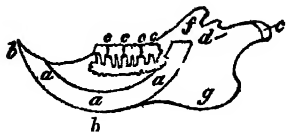
CHARLES.

But there are some animals, if I mistake not, which make a great use of their front teeth in gnawing, as rats and mice. I should imagine, that such animals would require some provision for a supply of cutting surface. Is such the case?

DR. A.

Rats, and mice, with beavers, squirrels, rabbits, hares, and a few other animals, are termed *rongeurs*, or *rodentia*, from the front teeth being employed

in gnawing; and you are right in supposing, that there is a particular provision, by which the surface, necessarily worn away in the operation, is supplied. In this tribe of animals, the incisor teeth have their fronts only covered with enamel, by which means they are sharp, and are adapted for cutting through solid wood; for the other part of the tooth, consisting of the common softer material, is worn away by attrition, and thus leaves the enamel of the front projecting and sharp, but necessarily in a continual state of destruction, by the use to which it is constantly appropriated. The mode which nature adopts for the purpose of supplying this daily waste, resembles, in some degree, that which is employed in the grinders of the elephant; for the incisors, instead of being shed, as in other animals, have the origin of their roots at a considerable distance in the jaw; and these roots being supplied by the constant augmentation and consolidation of pulp, the body of the tooth is carried forward, according as the friction has worn it down. You will be able to form an idea of this curious structure, from the little sketch which I now show you of the incisor in the squirrel; in which, *a a a* represents the bony part of the incisor, extending very far back to the root of the process of the jaw, and covered with enamel at *b b*; while *c c c c* are the grinders, *d* the cavity of the jaw for the admission of vessels, and *g* the angle of the jaw.



CHARLES.

Is any thing known concerning the chemical nature of the hard enamel which performs so important a part in the animal economy?

DR. A.

The solid part of bones, teeth, and enamel, consists principally of phosphate of lime, or bone-earth, united with a small portion of carbonate of lime, or chalk. This solid matter is, as I observed when we were on the subject of the bones*, capable of being removed by the action of acids; and then, in the case of bone and teeth, it leaves a considerable portion of animal matter, in which the bony substance was included, untouched. By the same process, however, the whole, or very nearly the whole of the substance of the enamel is entirely dissolved. It is, therefore, to the almost entire absence of animal matter, that the enamel owes its peculiar character; and it seems to be thrown out on the substance of the tooth, in a state nearly fit for assuming the crystallised form in which it ap-

* Vol. I. p. 119.

pears, instead of being the last of a succession of secretions, as is the case with bone. This, I stated to you *, was preceded by jelly and cartilage; but though these substances are absorbed, in succession, in the formation of bone, to make way for the hard material which is to give the bone or tooth solidity, yet this is not wholly the case; for you may recollect that boiling, as I mentioned to you, will dislodge a considerable portion of animal matter, in the form of jelly, and leave the solid, or earthy part, unaffected. This solid material is, to all appearance, destitute of further animal matter; but by long continued boiling under high temperature, as by the use of Papin's digester, (which is a vessel so contrived, as to admit the temperature to be raised much above the boiling point,) still more is to be obtained, which is found to be of a cartilaginous nature, and is what remains of the second constituent of bones, to form, with the cellular membrane, a frame-work, and permanent component part of their substances, which is so firmly adherent, as to have sometimes remained unaltered for centuries.

CHARLES.

Then, in fact, as bones are in a continual state of change, by absorption of old parts, and deposition of new ones, there must be a continual se-

* Vol. I. p. 116.

cretion of both jelly, cartilage, and bone, in order to keep up the relative proportions of each.

DR. A.

This must, of course, be the case, and therefore Harriet's idea, of the probable intermixture of those three substances in the composition of bone, was to a certain degree well founded.

HARRIET.

But as the teeth of man, and most other animals, when once formed, are destitute of the power of reparation, is there any reason for supposing, that the same process of renewal is going on in them, as in bone?

DR. A.

There has been a good deal of difference of opinion among writers of the best authority on the subject of the teeth, as to their precise nature; some regarding them merely as inorganic bodies, owing their sensibility only to the remains of nerves in the cavity designated in the section of the tooth which I showed you; others as possessing circulating vessels, and the ordinary accompaniments of common bone. The evidence in favour of their vitality is, however, very strong. They adhere firmly to neighbouring parts; and will take root again, if put in their places, or into the jaws of other people, as soon as extracted. They can likewise fix themselves, when recent,

in any whimsical place to which they may be attached, as the comb of a cock, if its surface be abraded. Putting aside their sensibility, which, as I have just mentioned, has been referred to the nerves existing in the cavity of the tooth, the fangs of the first set, though completely solidified, are capable of being absorbed by the pressure of those of the second, just after the analogy of absorption in other parts of the body. The circumstance, however, on which most stress has been laid, in order to show that some such process of absorption and renewal as that concerning which you inquire, goes on in the teeth, though with less force than in bone, and with much modification from the decay to which they are subject, is, that the teeth, as well as the bones of animals, are capable of being tinged by madder given to them for some time with their food; and that this colour disappears in a short period after the madder has been discontinued.—I mentioned to you that boiling will withdraw the animal from the bony part of bones; and acids, the bony from the animal. A consideration of the last circumstance, has given rise to the employment of dilute muriatic acid to remove the bony part of bones, and thus to leave a much larger portion of the animal material available, than can be obtained by almost any process of boiling. It has hence been ingeniously suggested, that if such cities as might at any time be in

danger of a blockade, were to have depositories of the bones of animals used as food established in them, there might thus be an almost inexhaustible store of nutriment provided for an exigency. A machine for bruising the bones, and a sufficient quantity of acid to separate the earthy part of them, are all that would be necessary for carrying on this process; while careful washing would readily separate the acid and saline particles, so as to prepare the animal matter for nourishment.—Before I take leave of this subject, I may mention, as connected with the incidental observations on the nature of bone, which I have now made, that the shells with which several marine and fresh water, as well as land animals are covered, consist principally of carbonate of lime, united either by jelly or cartilage; and that egg-shells, and the shells of the crustaceous animals, as lobsters, crabs, shrimps, &c. consist of carbonate of lime, united to a little phosphate of lime, and cemented with animal matter.

CONVERSATION XV.

OF DIGESTION.

DR. A.

During the action of chewing, the food is mixed with the *saliva* or *spittle*, which, as I have already mentioned *, is a secretion from three sets of glands, the parotid, submaxillary, and sublingual, placed in such a manner, that their ducts open into the mouth, and continually pour this fluid into it, but more particularly during mastication. The food is then carried backwards, and by the curious action of various muscles is thrown into the *pharynx*, which is a sort of pouch, or expansion in the back part of the mouth, from which it immediately descends, partly by its own weight, and partly by the action of muscles belonging to the pharnyx, into the *œsophagus or gullet*, at the extremity of which is the *stomach*, into which the food is deposited.

* Vol. I. p. 250.

CHARLES.

The gullet, then, I suppose, lies immediately behind the windpipe; but as we breathe through the same opening by which the food passes, there must be some method adopted, by which the food is prevented from ordinarily getting into the windpipe, which it now and then does, and producing great inconvenience.

DR. A.

The gullet and the windpipe lie parallel to each other for some distance. At the upper part of the gullet is the pharynx, which I have already mentioned; and at the upper part of the windpipe is the larynx, which is the projecting body that you may feel, just below the chin, at the front of the neck. It is hollow, and is connected with the windpipe, so as to admit air to pass through it, into the lungs. During the act of swallowing, the tongue is drawn back, and the larynx, upwards and forwards; so that the opening into it, through which the air passes is protected by the root of the tongue, and closed by a sort of valve or cover, called the *epiglottis*, which I shall have occasion to notice in speaking of respiration. To these circumstances, however, a certain action of muscles belonging to the larynx is added, by which the opening into it is closed; for it has been found that when the epiglottis has been removed, or has been lost

by disease, there is still a means existing, of closing the aperture into the windpipe during swallowing, and of therefore preventing the food from passing that way. It thus appears, that respiration is for an instant interrupted in swallowing, to allow the food to pass onward, without injury to the delicate and sensible organs concerned in carrying it on. But it is to be observed, likewise, that there is an opening from the nostrils into the pharynx, through which it is equally necessary that the food should be prevented passing, as down the windpipe. The soft palate of the mouth is carried backwards in the act of swallowing, and sufficient tension given to it by the action of the muscles which it possesses, so as to force on the food in its proper course; while the muscles of the larynx itself contract on the food admitted into it, and propel it onwards to the gullet.

CHARLES.

Does the food, then, when it is received into the gullet, pass on to the stomach by its mere weight; or has that tube any power in passing it forward? I should think there must be some muscular structure connected with it, for I have seen tumblers drink when they were standing on their heads; and we know that various animals feed and swallow, when their heads are close to the ground.

DR. A.

You are quite right. The tube is lined with a white smooth membrane, which is covered with a secretion of mucus, produced from some small glands below it, to keep it moist; but it consists chiefly of fleshy or muscular fibres, some of which are longitudinal, and some transverse, by means of which the gullet contracts upon any substance admitted into it, and drops it into the stomach. There is likewise, at the root of the tongue, a bone, of the figure of the letter υ, and hence called the hyoid, which serves to keep the tongue and palate expanded, and always ready, therefore, for the reception of food.

HARRIET.

You mention that the secretion of saliva is considerably increased during the act of chewing; but it seems also to be augmented by the mere appearance, or even thoughts of food, when a person is hungry.

DR. A.

There is certainly such a sympathy as that which you mention; and it appears, from a curious example which occurred some years since in Edinburgh, of a person who attempted self-destruction, by cutting across both the larynx and gullet, that during the cure, (for the person recovered after so

grievous an injury,) when nourishment was thrown into the stomach through the wound, there was always, by a sort of sympathy with the stomach, a considerable secretion of saliva from the mouth, to the extent of even from five or six, to eight ounces or more each meal.

HARRILT.

Then the quantity secreted in ordinary circumstances, is far more than one can have any idea of from one's own personal observation on the subject.

DR. A.

It has been supposed, that not less than a pound of saliva is ordinarily secreted during the 24 hours; and you may readily imagine this, when you consider the constant necessity which there is, to swallow the saliva which the salivary glands are continually pouring out. Any irritating substance, as tobacco, will increase the quantity exceedingly; and it is likewise capable of great augmentation, not only by medicine, but in various states of disease.

CHARLES.

I suppose the tartar which forms upon the teeth, when they are neglected, is to be attributed to the saliva in some way or other.

DR. A.

Saliva consists of more than 92 parts in the 100 of water; and as the remaining ingredients possess mucus, and some peculiar animal, with a small portion of saline matter, the mucus hardens when it is suffered to remain on the teeth, and in time forms what is called *tartar*, which is principally constituted of phosphate of lime, the production of which substance from mucus is rather obscure. A late examination of the white coating which often forms on the tongue, particularly of persons who are subject to indigestion, has however discovered, that it contains a considerable proportion of phosphate of lime; and is hence a probable source of the tartar of the teeth.—The saliva mixes difficultly with water, and, therefore, cannot be effectually removed from the teeth, but by brushing.

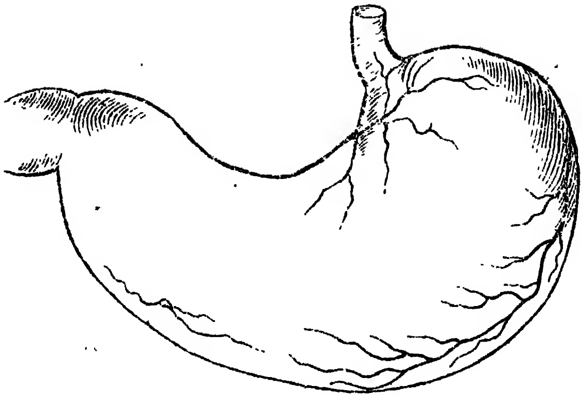
CHARLES.

The principal use of the saliva is, therefore, that of affording moisture sufficient to enable mastication to be performed adequately?

DR. A.

Certainly; and in this way it assists in the preparation of the food for the action of the stomach, which is the organ that I must now mention to you.

The STOMACH in man is a membranous bag, not very unlike the shape of the bag-pipe, lying across the body, and having two openings; the upper, towards the left side, by which it receives food from the gullet, called the cardia, from its supposed sympathy with the heart; and the lower, on the right side, called the pylorus, janitor, or porter, by which the food passes on to the intestines. Its inner surface consists of a soft, and rather pulpy membrane, called the mucous, or villous coat, which is carried through the whole alimentary canal; its middle, or body, consists of a muscular expansion, by which this organ is capable of emptying its contents; and its outer is a membranous covering, common to the stomach, intestines, and all the other organs contained in the cavity of the abdomen, and to which I shall afterwards have occasion to advert. The inner coat is united by cellular membrane to the muscular; but it does not contract with the contractions of the latter, and therefore frequently exhibits the appearance of folds. At the pylorus is a contraction which prevents the too ready passage of the food downwards. You will be able to form a correct idea of the shape of the stomach from the sketch which I now show you, in which the upper, or cardiac orifice, into which the œsophagus is inserted, is towards the right, while the pyloric is on the left side.



SOPHIA.

But I thought the stomach had been a very strong organ, capable of bruising and squeezing out the nourishment from the food which it receives into it. In what way, then, does it act in digesting our food?

DR. A.

Between its coats are various small glands, which are plentifully supplied with blood-vessels and nerves, and which secrete, and pour into the stomach, a fluid called *gastric juice*, which dissolves the substances taken into the stomach, converts them into an uniform, greyish, pulpy mass, called *chyme*, and thus fits them for becoming nourishment.

SOPHIA.

Is this, then, totally independent of any pressure which is exercised by its coats?

DR. A.

Entirely so; for it has been found that if portions of food were placed in silver balls, and these swallowed, such portions would be dissolved, notwithstanding they were placed out of the reach of pressure. Various interesting experiments were made, many years ago, on a German, who was in the habit of swallowing stones to gratify curiosity, by which this fact was satisfactorily made out.— When the food has undergone, to a sufficient extent, the change which it is meant to suffer in the stomach, it passes through the pylorus, or lower orifice, into the intestines. But care is taken that it does not quit the stomach too rapidly for the necessary changes to be effected in it. This is provided for by a sort of contraction at the pylorus, and by the food lying below it, so as to require a considerable exertion of muscular power to carry it up to, and then through this opening. When the food has passed into the intestine, it receives the *bile*, which is the bitter yellow secretion from the liver; and the *pancreatic juice*, which is the secretion of the pancreas, or sweet-bread. By the mixture of those substances, and of other secretions from the sides of the intestines themselves; and by the changes which are effected spontane-

ously, the food is so far altered in its nature as to be capable of affording *chyle*, which is a fluid, like milk, that is taken up by small vessels, called *lacteals*, from a large part of the surface of the intestines. These lacteals, uniting together, convey their contents into one of the large blood-vessels of the body, and thus supply the means of nourishment to the system. That part of the food which cannot afford further nourishment, is carried off as excrementitious matter.

HARRIET.

How very simple this view of an important process is. But it seems to me very extraordinary, that, whatever the description of food may be, there should always be chyle formed from it. Is chyle always of the same nature?

DR. A.

It is quite the same in all its more important properties, though there are some slight chemical differences; but the peculiar changes which are necessary for its production are very little known. Nature, however, has imparted to all animals certain powers of assimilation, by means of which, and the various decompositions and new combinations to which the food is subject, first, chyme, then chyle, and finally blood, are formed, of whatever aliment the animal may have been nourished.

SOPHIA.

Has this absorption of the chyle been seen in

animals which may have died during the process of digestion?

DR. A.

It is easily discoverable in any animal within five or six hours after eating; and I have seen it myself, very distinctly, in the body of a malefactor, which was given up by the law to surgeons for dissection. Through the whole course of the intestines there were small white lines perceptible, which were found to be the lacteals; and on opening any of them, a portion of milky fluid was capable of being collected.

CHARLES.

I have heard of fermentation going on in the stomach, and perhaps this may be evinced by the sense of distention which is sometimes felt, and by the occasional disposition to eructate.

DR. A.

These are both diseased feelings, for a perfectly healthy stomach has none of them. The discovery of the solvent powers which the gastric juice possesses, evinces that the process of fermentation is quite unnecessary for the conversion of the food into chyme, and afterwards into chyle. The frequent derangements of the stomach and alimentary canal, the overloading of the stomach, or the employment of food difficult of digestion, often prevent the agency of the gastric juice from

taking effect at the proper period. Detention of food in the stomach allows, in such cases, of the occurrence of fermentation, which some are disposed to consider as in the regular course of things.

CHARLES.

It is said that some animals, as birds, take in portions of gravel and stone, as if the digestion of the food were assisted by some sort of friction; and yet you say that digestion goes on independently of the pressure exercised on the food.

DR. A.

I have hitherto spoken only of the human stomach, which is of a membranous nature, and therefore totally unfit to press on the food which it may contain. All carnivorous animals have stomachs of the same kind; and I may remark of them, that animal, or mixed food, is more readily assimilated, that is, more readily converted into chyle, than any other description; and the digestive organs in such animals are of the more simple kind Many birds not only take in portions of gravel to assist their digestion, but as they have not teeth, and can divide their food in but a very imperfect manner with their bills or beaks, it is necessary that a more minute division should take place, in order to prepare it for the process of digestion. The *gizzard* of birds is therefore given them for the purpose; and it is

formed of two very thick and strong muscles, or rather one muscle with two bodies, and called, therefore, digastric, calculated to press any substance very strongly between the two parts of which it consists. But as the gizzard could not perform the whole of the duty at once, there is a bag, or enlargement of the gullet given to many birds, called the crop, which is situated in the front of the chest, at some distance from the gizzard. In this, the hard and dry food is macerated; it is then let into the gizzard, where it is bruised and divided; is mixed with the gastric juice, which is secreted by glands near the entrance of the gizzard; and thus the changes are produced which fit it for nourishment.

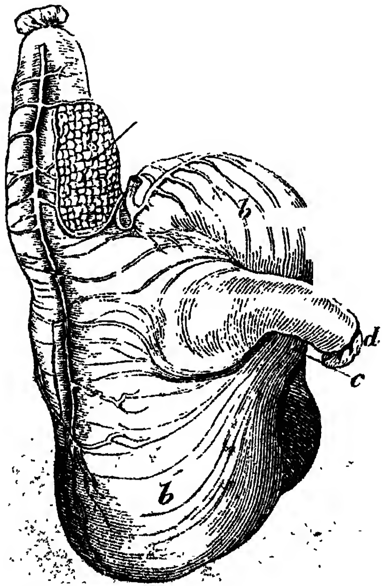
CHARLES.

It therefore appears that the stomach of such birds consists of two essential parts; the one, which triturates and divides, acting the part of teeth; the other, which secretes the fluid necessary for the solution and preparation of the food for nourishment.

DR. A.

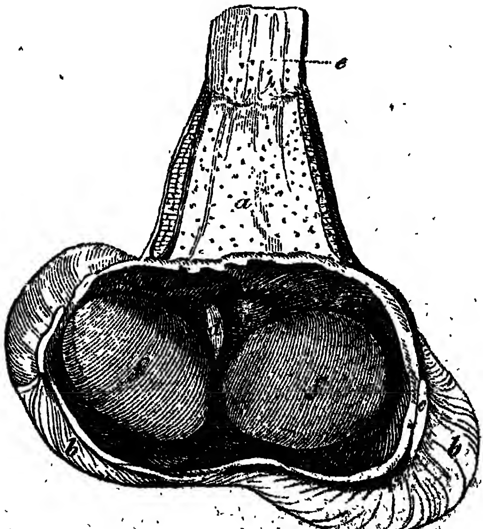
Certainly; and you will understand this the better, from a sketch which I shall show you, of the exterior and interior of the stomach, or gizzard, of a wild swan. In the view of the exterior, *a* represents a number of the glands which secrete the gastric juice, with their external extremities

exposed by a portion of the muscular coat being removed; *b b* are the fleshy fibres of the digastric muscle, which forms the great mass of the gizzard; *c* is the tendon which connects them with each other; and *d* is the commencement of the intestine, which carries the food downwards.



In the sketch of the interior of the gizzard of the same animal, you are to suppose it opened from above downwards, in the direction of the line

on the right, to the lower corner on the left, and the parts thrown back. Here *a* represents the orifice of the gastric glands in the interior of the stomach, answering to the glands *a* seen from without in the former sketch; *b b*, as in the former sketch, are the fleshy fibres of the digastric muscle divided; *c* is the tendon divided; *d* is the opening into the intestine; *e* designates the mucous glands around the termination of the gullet; and *f f* the cuticular, or horny covering of the gizzard, which is the part that triturates the food.



CHARLES.

At the time of trituration, the gastric juice is of course dropped on the food from the glands placed above.

DR. A.

This is the case, though the gastric glands vary in their position, being in some birds much lower down than in others; but there is a provision for the food not being too speedily carried onwards, by the intestine being joined to the gizzard very high up, so as by this means to allow sufficient time for completing the digestive process. The crop, in such birds as have one, is principally to be viewed as a repository from which the food is first softened, and then transmitted to the gizzard. But in all birds of the dove kind, and there is some reason to suppose this to be the case in parrots, mackaws, and cockatoos, the crop, both in the male and female, is endowed with a power of secreting a fluid, which coagulates into a whitish curd, and is employed to feed the young for two or three days after hatching. It is then found to be mixed with some of the common food; and as the pigeon grows older, the proportion of common food is increased; so that by the time it is eight or nine days old, when it is able to digest the common food, the secretion of the curd in the old bird ceases.

SOPHIA.

This is a very curious provision; and I suppose the kind parents have the power of sending up the curd without the mixture of common food, and of apportioning the respective quantities according to the age of the young.

DR. A.

This must either be the case, or they must accommodate their periods of taking food to the mixture which is required of it with the curd. But in either case, there is a wonderful display of instinctive knowledge.

CHARLES.

I have heard of the stomachs of ostriches being able to digest iron, and other hard substances: is there any truth in such stories?

DR. A.

The powerful gizzards of ostriches soon alter the shape of a strong metallic body, but can do no more. Balls of glass are, however, readily broken and powdered, by the action of the gizzard even of the common barn-door fowl.

SOPHIA.

I should have thought that the introduction of such substances risked a material injury to the animal.

DR. A.

So far from it, that needles, and even lancets, have been broken to pieces by the action of the gizzard, and no disadvantage sustained; for the hard tendon with which it is covered resists the strongest impressions.

SOPHIA.

The gizzards of fowls which one sees at table are hard and firm; but I should scarcely have thought them equal to a resistance so great as what you mention.

DR. A.

Because the tendinous part has been removed in the trussing, and the fleshy digastric muscle joined by the tendon on one side left; the other tendon being divided, so as to allow the muscle to be separated into its two divisions, and thrown back. In some of the crustaceous animals, as the lobster and crab, the division of the food is accomplished by means of teeth placed in the stomach, and covered with the same hard materials as the external coat. These teeth are of the molaris or grinding shape, and are one on each side. Immediately beyond them, is a single projecting tooth, which answers the purpose of preventing the food from passing on, till it is sufficiently divided. The stomach of these animals is also lined with a hard substance similar

to the external coat, so as that it is never collapsed; and it is a curious circumstance, that this coat, as well as the hard covering of the teeth, are parted with when these animals cast their shells. The tooth-like processes at the entrance of the mouth, which are sometimes represented as the teeth, are nothing more than a kind of pincers, to grasp the food, and convey it into the mouth.

HARRIET.

How extraordinary it is, that these animals should be able to digest their own stomachs and teeth.

DR. A.

This must be pretty nearly the fact; and I imagine that it is a provision against the injuries which these organs must occasionally meet with. In some of the worm tribe, teeth are likewise met with in the stomach; and such is also the case with various insects, particularly the Cape grasshopper, and mole cricket, of which last, there is a very accurate description, with plates, published by Dr. Kidd of Oxford, in the Philosophical Transactions for 1824.

CHARLES.

What special provisions nature seems to have taken for the proper division of the food. But is the peculiar structure which you mention in birds

common to all of them? for I should have thought such an apparatus unnecessary in those which live upon flesh.

DR. A.

Birds of prey, such as eagles and hawks, and those also which are principally carnivorous, as rooks, have stomachs that are nearly membranous. So have birds that live upon fish, which occupy a very large space, and are swallowed whole. These last, and also many of the birds of prey, have crops, or very wide gullets, which act either as repositories of food, or admit of a part of it being lodged in them, till the further part, which has reached the stomach, is digested; and then the remainder is taken in, and subjected to the same process. A friend of mine found a large rat in the crop of an eagle which was accidentally strangled by its chain; and another, partly in its stomach, and half digested, and partly in the gullet, contiguous to the stomach. A great power of distension exists in the serpent tribe, which are capable of swallowing large animals, the whole of which the stomach cannot receive at once. The boa constrictor, before it swallows an animal, prepares it for being taken down, by compressing it to as small a bulk as possible. There is, however, this very singular circumstance attending the stomachs of birds accustomed to live on animal food, that if, from the want of it, they are obliged to subsist on

grain, the digastric muscle forming the gizzard, which is hardly perceptible in them, becomes so large, that it can scarcely be recognized as belonging to the stomach of a bird of prey. This is strikingly exemplified by a preparation which I have seen in the Hunterian Collection, of the stomach of a sea-gull, which had been kept by Mr. Hunter for twelve months on grain, and acquired a very unnatural accession of strength in the gizzard muscles, from this change of food.

HARRIET.

Would the strength of the gizzard, do you suppose, be diminished, as well as increased by a change of food?

DR. A.

I have no doubt that this would be the case, if the experiment were tried, which I do not know that it has ever been; but it would appear, that all such birds as have naturally efficient gizzards, have them of various degrees of strength, according to the peculiar food which they are intended to use. Birds which are carnivorous, have various modifications of structure to accommodate the organ to the different descriptions of animal food. Some which take in grubs, and all sorts of insects, with their food, have a cuticular lining in the stomach, of various thickness, as a defence: others, which are in the habit of swallowing

bones, hair, and feathers, as hawks and other birds of prey, always regurgitate them; and so easily are their membranous stomachs irritated, that old books of hawking recommend, as a receipt for making a young hawk *cast* (as this operation is called), the giving three oats in a piece of flesh. When birds live on shell fish, and sea insects, their gizzards are strong, in order to break them, and at the same time to resist injury from their introduction.

CHARLES.

I presume, that as nature has made so great a difference between the stomachs of those birds which live on animal, and those which live on vegetable food, there is likewise a considerable difference between the stomachs of the carnivorous and graminivorous quadrupeds.

DR. A.

You will recollect, that animal food requires less assimilation than vegetable: and nature has, therefore, adopted various modes for facilitating the conversion of the latter into proper nourishment: one of the first means is a longer detention in the stomach; and this is effected, in many animals, by making the entrance of the cardia and pylorus near each other, so as to produce some difficulty in the passage of the food from the [illegible] of the stomach, nearly to the part from

which it was projected into it; thus a longer time is allowed for digestion. In the horse and ass, the left half of the stomach is of a different character from the right. It is lined with cuticle continued from the œsophagus, and the food is for some time detained in it; but it is at length gradually transferred to the right, or the digesting side of the stomach, which is covered with a villous coat, and is supplied with glands for the secretion of the gastric juice. The same structure, to a certain degree, exists in the hare and rabbit; but there is a very curious peculiarity in the horse; and that is, that the inside of its stomach is generally found covered with *botts*, a large sort of worm, which fix themselves firmly, by means of two small hooks, to the inner membrane of the stomach, and seem to be productive of but little inconvenience. They are discharged from the horse, go into the chrysalis state, and soon become flies. The eggs are deposited in such situations as to admit an entrance into the interior of the animal.

The most curious apparatus, however, for assisting in the conversion into nourishment of vegetable food, is that which belongs to the cow, the sheep, the deer, camel, and other animals which usually chew their cud.

HARRIET.

What is meant by chewing the cud? One

often sees this in cows and sheep; but I never could exactly understand why they should be so slow and leisurely in chewing at one time, and so rapid at another.

DR. A.

In chewing the cud, the food is brought up again for the purpose of being subjected to a second mastication.

HARRIET.

Do you mean, that, after being actually received into the stomach, it is subsequently disgorged for this second chewing?

DR. A.

It had been received into the first, or preparatory stomach, *the paunch*; for there are four stomachs which are concerned in digestion in these animals. The first stomach receives the food after a very slight mastication. From thence it goes into the second, the *honey-comb*, in small portions; and when it has been further macerated there, it is carried up into the mouth, by a sort of inverted motion of the muscular fibres of the œsophagus and stomach. It is then chewed, and passes into the third stomach, or *many-pies*, from whence it goes into the fourth, or *read*, the proper digesting stomach, where its conversion into chyme is completed.

HARRIET.

This is a very beautiful provision; but how is the food, which, in one case, is received into the first stomach, in another received at once into the third? Has the animal any power of allowing it to go into the one and not the other, at pleasure?

DR. A.

The two first stomachs, which are connected, as I have mentioned, with each other, receive their contents from the gullet, by a groove which is a continuation of it, having full projecting lips. The lower part of this groove leads into the third stomach, and this into the fourth. Now it is by the opening and shutting of this groove, that the operation in question is effected. When it is open, it is clear that whatever comes from above will have a lateral egress. Thus the food passes into the first stomach, because the groove opens immediately into it. But the groove is endowed with a muscular power, by means of which it is capable, at the pleasure of the animal, of being shut at the side, so as to form a tube continuous with the gullet. When this is done, the food swallowed, passes the first and second stomach, and gets immediately into the third.

SOPHIA.

How very curious is this structure; and how singular it is, that the animal should itself be able

to manage the actions necessary for carrying the various stages of digestion into effect.

DR. A.

This is a very admirable instinctive faculty, and it is the more wonderful, because under some circumstances, where the food is not of a nature to require, or to admit of rechewing, it is received at once into the third or even the fourth stomach. For instance, cows in the north of Scotland, and the Hebrides, are occasionally fed on fish, which does not require a second mastication, and is therefore received at once into the third stomach; and calves, which are fed entirely on milk, receive it into the fourth stomach, without even the intervention of the third, because the third has not been expanded by the reception of food into its folds, and therefore allows the milk to pass at once into the fourth; but in both those cases, there is a voluntary action of the muscles of the groove, which converts it at pleasure into a tight tube, suffering nothing to escape laterally.

CHARLES.

The process of opening and shutting the groove leading from the gullet, seems to resemble that of letting corn down the different chambers of a warehouse, through a hollow tube communicating from the top of the house to the bottom. If the tube is opened at any particular apartment, the

contents will be deposited there; but if it is closed, they will be carried to a chamber below.

DR. A.

Not a bad simile, and, as far as I know, an original one too.—The structure which I have mentioned, applies to most of the ruminant animals; but in the camel, there are some modifications, depending on the habits of the animal. The food is received into the first stomach, from which a muscular power raises it into the mouth for remastication. The second stomach consists of cells, and is solely appropriated to the reception of water, from which it passes into the third and fourth, which receive the food after being chewed. The third is very small, and the fourth is, as in the ordinary ruminants, that which is the immediate organ of digestion. There is a curious muscular structure in the camel, by means of which the orifices of the cells are closed, and the water preserved from being mixed with the food. It is this peculiar structure, which, in the camel, dromedary, and lama, fit them to live in sandy deserts, where the supplies of water are so very precarious.

CHARLES.

I have heard of the water being taken out of the bodies of dead camels in cases of great drought; and of these animals being occasionally destroyed,

in order to procure the supply of water which is found within them.

DR. A.

This has occasionally been done, as we are informed by travellers, in cases of great distress for water; and a miserable requital it is for the obligations due to the numerous services of these animals.

SOPHIA.

But is the quantity thus capable of being contained very great?

DR. A.

The cells in a camel which was dissected in London some years since, contained about two gallons; but I have no doubt, that they were capable of containing much more when in a state of distension; and I recollect that Bruce mentions, that four gallons were taken out of a camel during one of his journeys in a desert, where there was much distress from the want of water.

The division into a cuticular, and a villous or digesting portion, which I have mentioned as occurring in the horse, and some other animals, seems to be an intermediate state between the stomach of the ruminants and non-ruminants; and it is found that the kangaroo occasionally ruminates when fed upon hard food, and that its stomach is in part cuticular, and has a power of

contracting in folds, so as to have its contents easily brought up by the muscular action of the stomach. It has been supposed that there is an approximation to this structure in the human stomach, by a sort of contraction occurring between the right and left sides; and this, perhaps, derives some support from the occasional occurrence of rumination even in man.

HARRIET.

What, are there instances in the human race of chewing the cud?

DR. A.

A few are mentioned by authors; but the best-authenticated instance is one which came under the notice of Sir Everard Home. It was that of a young man of 19 years of age, idiotic from birth, and blind. He was very ravenous, and they were obliged to restrict him in the quantity of his food; since, if he eat too much, it disordered his bowels. Fluid food did not remain on his stomach, but came up again. He swallowed his dinner, which used to consist of a pound and a half of meat and vegetables, in two minutes; and, in about a quarter of an hour, began to chew the cud. Sir Everard states his having been once present on this occasion, when the morsel was brought up from the stomach into the mouth with apparently a very slight effort. He chewed it three or four times, and swallowed

it; when there was a pause, and other morsels were brought up in succession. This process was continued for half an hour, and he appeared to be more quiet at that time, than any other. But whether the regurgitation of the food was voluntary, or involuntary, could not be ascertained; as the young man was too deficient in understanding, to give any information on the subject.

CHARLES.

It appears, then, that the more simple stomachs are those which are intended to digest animal food, as being the most easily converted into nourishment; and that the more complex, either afford additional means of pressure or division, or require an additional period for the food to be acted upon.

DR. A.

This is quite the case; and nature has modified, in various ways, the process of digestion, and suited the kind of stomach to the description of food on which it is intended to act. But we must defer the further prosecution of this subject to another opportunity.

CONVERSATION XVI.

DIGESTION CONTINUED.

ABSORPTION.

HARRIET.

I WAS just going to remark, at the conclusion of our last conversation, that I wondered, considering what a powerful substance the gastric juice must be, to be able to dissolve the various matters which are employed as food, how the stomach itself is able to resist its influence.

DR. A.

Living animal matter has a power of resistance which dead does not possess; and examples are occasionally found, in which the gastric juice, after death, both in man and some quadrupeds, has corroded holes in the stomach, which was unaffected by it during life. It is in the same way that worms, botts, and such sort of animals are unaffected by a residence in the stomach and alimentary canal, in which they obtain their nourishment; but if they were to die, they would then be

unable to resist the influence of the digestive fluid, and would be dissolved, like any other extraneous substance.

CHARLES.

Has the gastric juice, when examined out of the body, any very strong or caustic characters?

DR. A.

None by which you can infer any thing like the effects which it is capable of producing. It does not differ much in appearance from saliva; and in sensible qualities it is slightly bitter and saline. It possesses, out of the body, in some degree the same property of reducing substances to a pultaceous, chyme-like mass, which it has in the stomach.

SOPHIA.

But how is the gastric juice procured for the purposes of examination?

DR. A.

Sometimes it has been obtained from the stomachs of animals after death, who had fasted a good while previously; sometimes by making animals swallow portions of sponge, which were withdrawn on being filled with the fluid of the stomach; and sometimes by the action of vomiting on an empty stomach. The gastric juice has the power of coagulating, which seems to be the first

process of digestion in such substances, as milk, which admit of coagulation. Hence an infusion of the fourth, or digestive stomach of calves, as being imbued with gastric juice, is usually employed to coagulate milk; and so small a quantity answers the purpose, that seven grains, infused in water, were found to afford as much fluid as coagulated 100 gallons of milk; that is, more than 6857 times the weight of the substance employed.

CHARLES.

Then it is probably of an acid nature, since acids so remarkably possess this property.

DR. A.

So little is this the case, that it has been found that a portion of the stomach of a calf, if even kept for some time in an alkali, still retains its characteristic property.

HARRIET.

Is this property of coagulating common to all stomachs?

DR. A.

Such seems to be the case; for Mr. Hunter found it to exist in the stomach of the boar; in the crop and gizzard of fowls; and in the stomachs of sharks, salmon, and thornbacks. It appears that it is owing, in all animals, to the secretion of the gastric

juice, though its mode of producing this effect is unknown. The gastric juice has likewise a remarkable power of checking putrefaction in any half putrid aliment which may be taken into it: and the same power is exercised on similar substances out of the body.

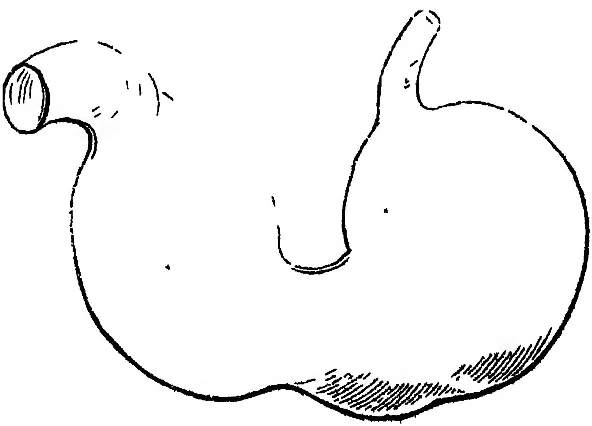
HARRIET.

When animals swallow flesh and bones with undiscriminating voracity, is the gastric juice able to dissolve the bones?

DR. A.

The stomachs of dogs and hyenas have very remarkably that property; and the teeth of the latter are most formidably adapted to crushing bones, and preparing them for the action of the gastric juice. Even ivory, and the enamel of the teeth, are dissolved in the stomachs of dogs; and that of a hare has dissolved an onyx, and diminished a louis-d'or. But the external husk of vegetables very singularly resists the operation of the gastric fluid, as in the case of oats with horses; or the seeds of apples and other fruit with man; but when these substances are bruised, or triturated, they are then acted upon in the usual way.—The endeavours of chemistry to ascertain the nature and mode of operation of the gastric juice, have hitherto been very unsuccessful. Its operation seems to be very much confined to the food which

is contact with the surface of the stomach, and it is in greatest force at the larger end, which is on the left side of the body, as you may see by the sketch. The mass of food is slowly passed on by the muscular action of the stomach, to the smaller end, and from thence to the pylorus; and it appears that any new food which is added, is kept separate from the old, being in the centre of the latter, and therefore not subjected to the action of the gastric juice, till that first received has been converted into chyme. I have already mentioned to you the division into a right and left portion, which some physiologists consider as occurring during digestion. The sketch which I now shew will enable you to form an idea of this.



CHARLES.

The power of converting substances of various kinds into animal flesh, of the same appearance and nature, is a wonderful operation, which seems to be intended to make every thing useful; for if animal flesh could only be produced by animal flesh, the whole of the vegetable kingdom would, as far as nourishment goes, be altogether useless.

DR. A.

And yet you are not aware still, of the full extent of the provision which exists for the support of animal life. For instance, there are substances which would act as poisons to man, which are salubrious, and nutritious to many of the brute creation; and some things which are grateful and nourishing to one animal, are offensive and hurtful to others. The sheep and goat will feed upon hemlock, and the pig upon henbane, which are poisonous to man; opium does not affect the dog, and yet bitter almonds are poisonous to him. There is likewise a wonderful power in the stomach of accommodating itself to varieties of food; so that the graminivorous can occasionally be made to feed on animal food, and the carnivorous on vegetable. I have already mentioned the change produced on the stomach of a sea-gull which was fed on grain; the stomach acquiring a

great increase of muscular power, which the change of food rendered necessary.

But man, of all animals, possesses the greatest power of accommodation to the varieties of aliment which different climates afford. In the high latitudes, his food is entirely animal, and often of the most forbidding nature, according to our conceptions; as raw whale, seal blood, dried herrings moistened with whale oil, &c.; while in the torrid zone, he is supported principally by fruits and vegetables. Though we are the creatures of habit, the same individual can likewise bear great varieties of sustenance; and with regard to the particular effects of animal or vegetable diet on the physical powers of man, we have examples of strength, activity, and bravery, in the Greeks and Romans of ancient times, and in the Irish and Scotch of modern, under the employment principally of vegetable food.

For the purpose of ensuring the proper support and nourishment of the body, nature has wisely given the strong impulse of hunger and thirst, by means of which animals are led, by a law of continual operation, to look out and procure for themselves, a proper quantity of food. Some have thought that the immediate cause of hunger was mere emptiness, by means of which the coats of the stomach either spontaneously, or through the means of the folds produced in the villous coat, by

the contraction of the muscular, rub against each other, and produce the peculiar sensation. Others are of opinion, that it is attributable to a certain degree of irritation produced by the action of the gastric juice; and others, that it is to be considered as a sensation depending on sympathy with the wants of the system at large. None of these opinions appear to be sufficiently established: but the immediate cause of the sensation is not well understood: that it is however connected, in some obscure way, with the nervous system, seems to be obvious from the circumstance, that any powerful affections of the mind, particularly grief; any interesting and absorbing employments; and various narcotic substances, as opium, tobacco, betle, or ardent spirits, will suspend or diminish the disposition to take food. The existence of a mechanical agency in producing the sensation of hunger, seems to be likewise contradicted by the well-known fact, that appetite will often entirely disappear, if the hour of taking food is passed over; though one has heard that the swallowing balls of earth, and the application of tight ligatures round the body, will, in some cases, deaden the feeling of hunger.—A good deal of the same difficulty attaches likewise, to an endeavour to account for the existence of thirst. This sensation seems to be much connected with various derangements of the system, and it is but seldom

dependent on absolute privation of drink, as hunger is of food. We principally refer it to the mouth and fauces; yet in that extraordinary case which I mentioned to you, of a wound in the gullet, no quantity of water taken into the mouth, and passed out at the wound, could quench thirst; but a small quantity of fluid, particularly weak spirit and water, injected into the stomach, remarkably abated it.

When the food has remained as long in the stomach as is necessary for its conversion into chyme, an action of its muscular coats takes place, by means of which it is passed on to the pylorus, and through this into the intestines; and here I may observe generally, that in graminivorous animals, the canal is longer than in man and carnivorous animals, in order to afford still further time for assimilation, and for the nutritive part to be taken up. In the lion, the intestinal canal is about 4½ times the length of the body; in man about 5½ times; but in the horse it is about 11 times, and in the antelope 18 times.

CHARLES.

Is there any distinction made between the different parts of the intestines?

DR. A.

The intestines are divided into the small and large. The small, are those which are immediately

continuous with the stomach. They consist of, 1st, the *duodenum*, which is so called from its being about twelve inches long; 2d, the *jejunum*, from its being often found empty; and, 3d, the *ileum*, from its occupying the iliac region, or that between the two hip bones. — The small intestines are mostly occupied in perfecting the assimilation of the food, and in affording an opportunity for its absorption. — The large intestines are a continuation of the small, and are termed, 1st, the *cæcum*, which is so called from its being, in some degree, a cul-de-sac; 2d, the *colon*, which nearly encircles the abdomen, and terminates in, 3d, the *rectum*: and these three last are the receptacles of the food, after having parted with most of its nourishment, and become excrementitious.

CHARLES.

Does the structure of the intestines bear any analogy to that of the stomach?

DR. A.

It is very similar, there being a villous or mucous lining, followed by layers of longitudinal and circular fibres, and then by an external covering, which is common to all the organs contained in the abdomen. By means of these muscular fibres, the food is gradually carried downwards, by a sort of gentle vermicular motion, which is technically termed the *peristaltic motion* of the intestines. Next

to the stomach, the most important change which the food undergoes is in the first intestine, the duodenum, where the bile and pancreatic juice are added to it; but over the whole course of the canal, fluids are poured into it from the exhalent vessels, for facilitating the conversion of the food into nourishment, or for covering and defending the inner coat from injuries by the occasional passage of any irritating matter. The *bile* is a yellow bitter fluid, secreted from the liver, and poured into the duodenum at a short distance from the stomach. There is also a little receptacle for the bile, which is called the *gall-bladder*, and in this, gall-stones, when they occur, are formed, which often give extreme pain in their passage into the intestine.

SOPHIA.

It is very usual for persons to be bilious; and I presume this is from some disease in which the bile is concerned.

DR. A.

Bilious, and nervous, are two terms which have no well-defined meaning annexed to them. Persons call themselves, and are often termed bilious, who are subject to some one or other of the various affections in which the stomach or bowels are concerned; but in by far the greater number of such complaints, the liver is only concerned as

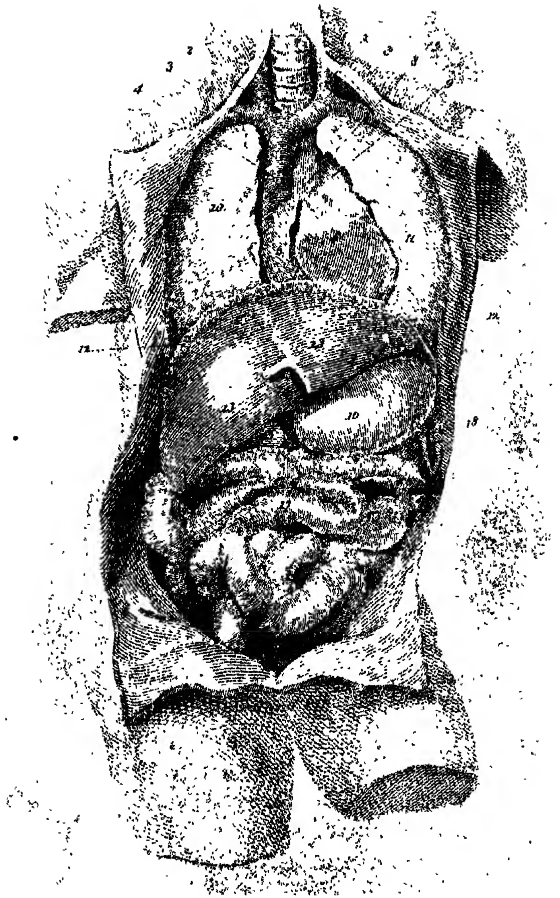
a part of the organs of digestion, and in no other, or primary way.

HARRIET.

People are often said to have affections of the liver: and, indeed, one would imagine, to hear of the frequent attacks of this organ, that it is the most susceptible one of the body.

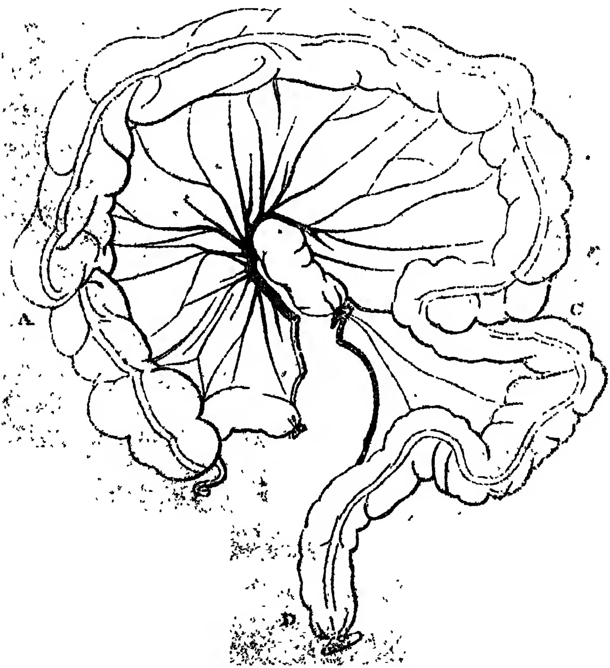
DR. A.

It is a very important organ, and, in warm climates, it is particularly liable to disease. In the more temperate, however, it is much less so; and it often happens, that diseases are referred specially to the liver, which are only affections of the large intestine, the colon, which is contiguous to it. The LIVER is a large, firm, and dusky red-coloured organ, which is on the right side of the body, lying directly under the ribs separated from the chest by the diaphragm, and not capable of being discovered by the touch, unless it is enlarged. It is divided into two principal parts or lobes, and the left one lies over the stomach. It is liberally supplied with blood-vessels, and from the extremities of these vessels the bile is secreted, which arises in small tubes, that unite into larger ones, and then into a duct, by which the bile passes either directly from the liver into the intestine, or into the gall-bladder, and from thence is thrown into the intestine. But the bile, in the latter case, is of a thicker and darker description than when



it comes from the liver directly. There is a curious structure which nature adopts, to prevent a tube, which is destined to throw out a fluid from any organ, from allowing its return. This, it is clear, would be liable to happen, if it entered at a right angle, or any thing like it; but, instead of doing so, it pierces the external coat very obliquely, then passes on between the coats, and enters the intestine in such a way, that the inner coat of the latter acts as a valve, and is shut against pressure from the intestine. A similar structure is adopted in throwing the *pancreatic juice* into the intestine. This fluid much resembles saliva, and has an operation in promoting the [illegible] of the food, which is but little [illegible] se-creted by the PANCREAS or [illegible] an organ which [illegible] across the abdomen, and is [illegible] glandular structure; and it is thrown into the intestine through a duct having an opening common to it and the bile. You will be able to understand the relative positions of the stomach, gall-bladder, duodenum, and pancreas, from the sketch which I now shew you, in which A is the stomach; B B the duodenum; C the gall-bladder; E F G the gall ducts, of which E is the hep[illegible] duct, which brings the bile from the liv[illegible] the gall-bladder and the intestine; [illegible] which takes it to the [illegible] the common duct which [illegible] and the

you may judge of their position from another sketch, in which A designates the commencement of the colon, with the ileum attached to it at its bottom, ascending past the liver; and B, the arch of the colon, passing under and close to the stomach: at C, the colon forms what is called the *sigmoid flexure*, from a resemblance of its curve to the letter sigma, and terminates in D the rectum.



Over the whole of the intestines, I must observe, is thrown a thin double membrane, often containing much fat, which is termed the *omentum* or *cawl;* and the substance by which the various intestines are joined together is called the *mesentery*.

CHARLES.

There is, I suppose, some mode by which the liver is supported, for its weight would otherwise be likely to carry it downwards?

DR. A.

This is effected, both in the liver and other organs, by what are termed *ligaments*, by means of which these are tied or united to some fixed parts. In the case of the liver, its principal adhesions are to the diaphragm, which, as I mentioned before, is the partition between the cavity of the chest and the abdomen.

CHARLES.

Are these ligaments fixed to any particular part of the diaphragm or liver? I can understand how a ligament is fixed to a solid body, as a bone; but it is more difficult to conceive an attachment to a soft part.

DR. A.

This involves a very curious and important part of abdominal structure, which I must endeavour to explain to you. The whole of the walls of

the cavity of the abdomen, including the diaphragm, are lined with a thin fine membrane, called *peritoneum*. This membrane affords an external covering to the liver, spleen, stomach, and intestines; and by the doubling over, which necessarily occurs at various places, there is a binding of the different parts together. Thus at the diaphragm, the peritoneum, instead of covering the whole of this partition without interruption, is reflected over the liver; and if you can conceive the two surfaces brought around it so as to unite, you would then have a ligament, or bond of union formed, and the large heavy body of the liver prevented from descending. It is in this way that various doublings or folds of the peritoneum are formed, which are important in the minuter anatomy of the abdomen.

CHARLES.

I must own that I cannot quite understand the account which you give of the peritoneum; or how it can afford a covering to the viscera of the abdomen, without being in separate pieces.

DR. A.

If you suppose this room to be lined with chintz, or any other thin material, how would you contrive to cover the cabinet, which stands at a little distance from the wall, by a mere prolongation or fulness of the chintz?

CHARLES.

We must bring it round the cabinet first, and then make it firm to the wall.

DR. A.

That would merely cover the front and two sides of the cabinet, while the back of it is uncovered, as well as the wall which answers to the back. This does not accord with the description, which I give you of the peritoneum, that it covers the walls as well as the furniture of the abdomen.

CHARLES.

If we carried the chintz round the cabinet, and brought the two ends together behind, we should cover the cabinet; and then the two ends, by being separated, would cover the wall completely behind it.

DR. A.

This is the mode in which the peritoneum covers the abdominal viscera and the walls of the containing cavity. If you suppose separate pieces of furniture, all which require covering by means of the chintz, you will see clearly that an uninterrupted prolongation of the same material, may give a covering to various separate, and very irregular bodies.

HARRIET.

Then these bodies must all be joined together

by a double fold of the peritoneum, just as it happens that there is a double fold of chintz at the back of the cabinet joining it to the wall.

DR. A.

This is exactly the case; and you see that there is, by this means, an attachment of the cabinet to the wall, just as happens in the abdomen, where there is an attachment of the liver, and the other viscera, to neighbouring parts, by the doublings of the membrane, which affords them all a covering. If you were to suppose all the furniture of the room covered with prolongations of the same lining, there would then be various doublings from the walls or floor, in order to accomplish the purpose. In this way, the various meanderings of the intestines are held together; and the doubling by which this is effected is termed the *mesentery*. Where strength of support is required, there are firmer and tighter doublings provided; where attachment only is wanted, the covering is loose.—It is merely necessary to notice the SPLEEN, which is another of the viscera of the abdomen, and lies, as I have already mentioned, on the left side of the body, contiguous to the stomach, to which it is attached by blood-vessels. It is of a dark purple colour, very full of blood, of an irregular, flattened, oblong figure, and with no perceptible duct. Its uses have not yet been ascertained; and

that they are not of prime consequence in the animal economy, is apparent from the circumstance, that it has been removed from dogs, without affecting their health. It is apt to be enlarged by residence in a tropical climate; and in this case forms what has been vulgarly termed the ague cake, from its frequently being the consequence of intermittent complaints. — In addition to the abdominal viscera which I have mentioned, I may remark that there are two or three other organs not suitable for elucidation by conversation, and which must, if they are made the subject of attention, be studied in books.

CHARLES.

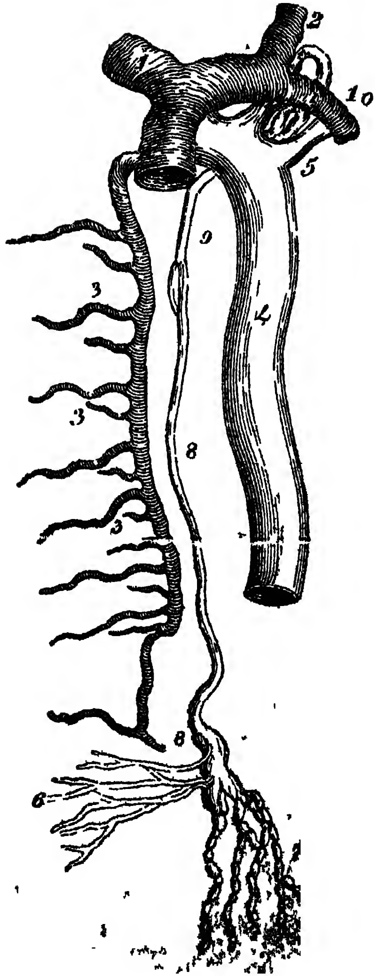
It appears from what you have stated to us on the subject of digestion, that this process consists of two series of operations; one occurring in the stomach, by which the food is converted into chyme; the other in the bowels, by which it is converted into chyle; for I presume that chyle is never to be found in the stomach.

DR. A.

It makes its first appearance in the duodenum, after the mass which has been transmitted from the pylorus has been mixed with the bile and pancreatic juice; but it is continued to be formed during the whole course of the small intestines. Over the whole interior of these intestines, and more sparingly in the large ones, minute vessels,

called *lacteals*, as I mentioned to you, open, for the purpose of taking up the chyle. They carry it on to the mesentery (that part of the doubling of the peritoneum which unites the folds of the intestines together), to several series of small glandular bodies, existing in the substance of the mesentery. Over them the lacteals are divided into minute ramifications, unite again into large branches, are again dispersed over other series of these glands three or four times, and then again produce a small number of larger trunks, which join in forming one long one; which is called, at its commencement, the *receptaculum chyli*, or receptacle of the chyle, and in its continuance, the *thoracic duct*. These, together, form a small membranous, tortuous canal, several inches in length, about the thickness of a small quill, and a little wider at its commencement, where it is termed the receptacle of the chyle, than in its progress. It lies close to the spine, accompanies some of the large blood-vessels, and, ascending to the upper part of the chest, delivers its contents into a large vein near the heart, called the left subclavian; and these contents then form a part of the general mass of blood. The whole process is termed ABSORPTION. You will be able to form some idea of the course of the thoracic duct, from the little sketch which I now shew you, in which

No. 1. is the left subclavian vein;
2. the internal jugular vein,


1
2
10
5
9
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8
6

3. part of the vein called azygos, or vein without a fellow;
4. part of the descending aorta, or great artery;
5. the subclavian artery.
6. lacteals entering the receptacle of the chyle;
7. lymphatics entering ditto;
8, 9. the thoracic duct;
10. the entrance of the thoracic duct into the subclavian vein.

HARRIET.

How very simple and intelligible you have made this route of the chyle to the circulating system. But is the chyle, in its milky form, fitted at once to unite with the blood, and perform its various functions?

DR. A.

By no means. It has to pass through the circulation; and there you will find, that there are some processes to which the compound fluid must be subjected, before it is adapted to nourish the body.

CHARLES.

The divisions which the lacteals suffer in the mesenteric glands are, I presume, intended to complete the adaptation of this fluid to entering the blood.

DR. A.

Such a purpose is exceedingly likely; but we

know very little of the particular structure of glands, so as to be able to form any conjecture as to the mode in which nature makes them useful. The proper and pervious state of the mesenteric glands is essential to the health of the body; for in case of their obstruction, or of their want of due action, the chyle is imperfectly taken up, or unduly elaborated; and as the system is in this way not adequately nourished, emaciation takes place. Mesenteric disease is therefore a very formidable complaint, and is such as children are particularly liable to, more especially in large towns; though it is very probable that complaints ascribed to the mesentery alone, belong to much of the process of digestion and assimilation.

CHARLES.

The mouths of the lacteals take in their contents, I suppose, by capillary attraction; but I cannot understand, in this case, why they should not imbibe any fluid, whether nutritive or not, which may be applied to them.

DR. A.

There seems to be a power of contraction in those vessels, by means of which they refuse entrance to any substance of an injurious nature.

CHARLES.

But in what way are the contents propelled? for

capillary attraction would only operate while the vessels were of a certain size.

DR. A.

Throughout both the lacteal vessels, and thoracic duct, valves are placed, which prevent the fluid which has once entered them from regurgitating; and a valve likewise exists for the same purpose, at the termination of the thoracic duct, in the great vessels which I mentioned to you that it joined. These valves give a knotted appearance to the lacteals and thoracic duct, and seem to be produced by a doubling or folding of the inner membrane of the tube. In this way the return of the chyle is prevented; but there is likewise a contractile power allotted to the lacteals and thoracic duct, by means of which a contraction takes place over their contents, so as to propel them forward. If there had not been valves, the action might have thrown the contents either way, and thus part of such action would have been lost; but with this structure, all the contractile force is employed in propulsion.

CHARLES.

There must then, I suppose, be a muscular structure in the lacteals and thoracic duct, to produce this effect.

DR. A.

The coats are too thin to admit of such a struc-

ture being discovered by the eye; but the vessels, though very thin, and indeed imperceptible when empty, are very strong, and have a power of emptying themselves even after death; since the lacteals which may be visible on the mesentery of animals immediately after death, from having chyle in them, soon cease to be so, from the chyle being passed onwards. The thoracic duct likewise, on being opened, has been known to throw off its contents, like blood from a vein. It is to be observed, that there is a similar structure both in the veins and the lacteals, which assists this motion, viz. that the trunk is smaller than all the branches united; so that an acceleration is given to the current, the nearer the fluid approaches to the trunk of the absorbing vessels. There is still, however, a good deal of difficulty attaching to the mode in which the motion of the chyle takes place, and an ingenious idea has lately ascribed it, in some degree, (as I shall have occasion to mention to you, when I speak of the mode in which the circulation of the blood is carried on,) to the effects of atmospheric pressure operating during the act of inspiration.

HARRIET.

It is certainly a very extraordinary circumstance, that animal and vegetable food, which are so very different in their nature, should both of them in

time be equally converted into blood, and, through the medium of this, into all the varieties of substances which exist in the animal body. If the ultimate elements of both were the same, there would be no difficulty in the idea; but if this is not the case, it seems to be by a sort of transmutation, hardly less perfect than that of lead into gold, by which grass, for example, is so altered in the digestive organs, as to be capable of conversion into muscular flesh.

DR. A.

We can hardly admit the production of a new substance, without the materials being afforded of which it consists; and if we cannot account for the access of these materials, it only evinces that our knowledge of the ultimate analysis of the bodies from which such new substance was derived, or our acquaintance with the other sources from which its component parts might originate, are not sufficiently accurate. The great general distinction between ordinary animal, and ordinary vegetable matter, is the absence or paucity of azote in the latter; for by ultimate analysis, oxygen, hydrogen, and carbon are found to be common to both, though in unequal quantities. What may be the source of that large portion of azote, which forms so important a feature in animal composition, is a matter of question;

and whether it may arise from the decomposition and new combination of substances, which we have been in the habit of regarding as simple, has not yet been determined. The most accurate researches of some of our most scientific chemists have pursued the food from its entrance into the stomach, through all the successive changes which it undergoes there, and in the small intestines, and also in various parts of its course, as chyle, up to its combination with the blood; and it has been found that material changes of nature in the nutritive part of the aliment take place through every part of the progress, by means of which the vegetable matter becomes more and more animalized, and the animal, more and more made to approximate to the nature of blood. It is very probable that varieties may even occur between the precise nature of the gastric juice and other secretions to which the food may be exposed in its progress, so as to assist in the more ready animalization of the vegetable matter; and as we exist in a fluid, the atmosphere, of which the larger part consists of azotic gas, it has been rendered probable, (as we shall find on the subject of respiration,) that a supply of azotic gas may take place from the atmosphere, which may have some effect in making up the balance rendered necessary by the use of vegetable aliment alone. The transformation of vegetable food into animal matter, is

still, therefore, a subject of great difficulty with physiologists.

CHARLES.

The production of the solid material of bones, the phosphate of lime, must, I should conceive, be a matter of some difficulty in the theory of digestion; unless the food, whether animal or vegetable, be considered as affording sufficient for the purposes of the system.

DR. A.

Lime is one of the most universally diffused bodies in nature, and it would not be difficult to suppose, that enough of this might be afforded by the aliment for ordinary purposes; but then there are some animals, as the testaceous and crustaceous, in which so large a quantity is requisite, as to make it impossible to consider the supply as depending entirely on the food taken in. Some accurate observations have been made as to the quantity of calcareous matter produced in eggs in a certain time, by a hen fed in a known way; and it has been satisfactorily ascertained, that more calcareous matter was elicited, than could be accounted for by that which was received as aliment. Here, therefore, there was either a generation of such calcareous matter by the powers of the system; or this substance must be a compound body, formed by some decompositions, or new combinations of substances,

whose chemical nature and mode of combination have not been sufficiently understood. Similar difficulties have occurred in the vegetable kingdom; for in answer to a prize-question proposed by the Berlin Academy, to determine the constituents of the different kinds of corn, and to ascertain whether their earthy part is formed by the process of vegetation, it was at length discovered by Schrader, a Prussian, that seeds will grow and produce corn, yielding as much, or more earthy matter than the original seed, when removed from all contact of earth, and watered merely with distilled water. The experiment was made on seed planted in sulphur, placed in a garden, at a distance from all dust, in a box to which the light and air had free access, but from which all dust and rain were carefully excluded. In confirmation of the same extraordinary circumstance, Saussure found, that plants growing in a calcareous soil, which contained little or no silica or flint, will, nevertheless, yield a considerable portion of that substance; and other chemists have discovered in the ashes of some descriptions of pines, more than 65 per cent of lime, when no traces of this substance could be found in the soil. All these circumstances, therefore, discover that the powers of chemistry are inadequate to detect the processes which are continually carried on in the animal, as

well as the vegetable economy, for supporting life and promoting growth.

HARRIET.

You spoke, when you were on the subject of the brain and nervous system, of galvanism having some influence on the function of digestion. In what way does it bear upon the process?

DR. A.

Digestion is found to depend on a certain influence propagated from the brain to the stomach, through the medium of a particular nerve which passes down the neck and back, and is called the par vagum, or wandering pair of nerves. If these nerves are divided, and a portion of them removed, digestion is suspended; but it is restored on substituting galvanism for the natural nervous energy, and hence it has been conceived, that nervous and galvanic influence are identical.

In mentioning to you the lacteal vessels, I have omitted the notice of another very important part of the absorbent system; namely, the *lymphatic vessels*, the contents of which are carried into the blood, partly through the medium of the thoracic duct (No. 8, 9. Page 209.), and partly by separate junctions with the large veins themselves, near the place where that duct joins the subclavian vein.

HARRIET.

I recollect that you gave us an outline of the lymphatic system, when you conversed on the subject of the bones; and I well remember how curious we considered the continual deposition and absorption of the various parts of the body, which you then mentioned to us.

CHARLES.

By means of the lymphatics, the body seems to live upon itself, since the fluid which they contain, is thrown into the mass of blood, with what is intended for nourishment. But is there any similarity in the structure of the lymphatics, compared with the lacteals?

DR. A.

A very considerable one, both in appearance and texture; and both sets of vessels pass through glands, and are endowed with valves, in order to prevent regurgitation. The glands become apparent, as well as the course of the lymphatics themselves, when the extremities of these latter are irritated, or in any other way injured. For instance, when leeches are applied to any part, the bites will occasionally fester, and in this case, if the part should be the hand, red lines will be seen extending up the arm, and running to the arm-pit, in which a small painful knot may be felt, which is an inflamed lymphatic gland. Medical gentlemen have

sometimes severe affections of this kind, from accidental cuts or scratches got in dissection.

CHARLES.

Would the lymphatics be capable of being seen as white lines immediately under the skin, as you have mentioned to be the case with the lacteals in the intestines and mesentery?

DR. A.

The lymphatics are always invisible, for the fluid which they contain is pellucid like water, and not of a milky nature like chyle; and the trunks into which all of them unite, may be seen to pour a watery material into the thoracic duct, (No. 7. page 209.) or into the subclavian vein when they terminate directly in that.

SOPHIA.

Except for this proof, it would be very difficult to conceive the existence of such a minute system of vessels, containing a transparent, and therefore an invisible fluid.

DR. A.

It is not, however, left to mere general inference, however probable, to conclude concerning this system of vessels. By great nicety, a lymphatic vessel is capable of being discovered, and of having a very small tube fixed in it, communicating,

or continuous with a larger one containing mercury. The weight of the mercury forces on the minute stream, first into branches, and then into trunks, till not only the existence of lymphatics is discoverable in all parts of the body, but their union in glands, their departure from them again in branches, their subsequent union in trunks, and the congress of their trunks in a common centre. In this way, the whole body has its lymphatics filled with mercury, so as to exhibit an extensive series of vessels over every part of it, communicating freely with each other; so as that if one gland is obstructed, the fluid may be carried on, without interruption, by uniting branches, which have passed through other glands. I may mention to you, that lymphatics have not yet been discovered in the brain; but there can be no doubt of their existing there, as well as in other parts of the body.

SOPHIA.

I take it for granted, that lacteals and lymphatics exist in all animals.

DR. A.

An absorbent system has been discovered in the mammalia, birds, amphibious animals, fishes, and insects, and something of a similar kind must also exist in the lowest orders of the creation. Throughout the mammalia, there is a very great resem-

blance in the lacteal and lymphatic system; and in all of that class, the chyle is white and milky. In birds, the chyle is transparent, as well as the lymph; and in them, as well as amphibious animals and fishes, there are few or no glands and valves. There are various differences in animals, in the direction and course of the lymphatic vessels, and in the variety of shape and number of the trunks in which they terminate.

HARRIET.

There seems to be this curious difference between the action of the lacteals and the lymphatics, that the former only take up one particular substance, chyle, while the latter appropriate to themselves every thing with which they come into contact. It seems as if they blended together all the materials of which the body is composed, whether bones, flesh, or membrane, into one general and uniform mass, to be again and again made subservient to the purposes of the animal economy.

DR. A.

This is the case; and a singular and beautiful circumstance it is, that there should be such a great and unceasing activity employed, as I before explained to you, over every part of the system, in moulding it to its particular form, in taking off what is injurious, and in contributing to a due balance of

action in the various parts of the animal body. But the lymphatic vessels, it is necessary to mention to you, not only carry back into the system what originally belonged to it, but from their diffusion on the skin, have the power of imbibing, sometimes spontaneously, and sometimes by means of friction, substances which come in contact with the skin. Thus portions of mercury, lead, and other deleterious substances, can be taken in, and produce well-marked effects on the system, through the medium of the skin; and moisture can be absorbed by the skin, either when the body is immersed in water, or in air, though in various degrees according to the condition of the animal, and the circumstances under which it is exposed.

CONVERSATION XVII.

OF THE CIRCULATION OF THE BLOOD.

DR. A.

WE have followed the course of the nutritive part of the food, up to its introduction into the circulation; and in natural order, we come now to consider the mode in which the circulation of the blood is carried on.

THE HEART and BLOOD-VESSELS are the organs employed in this process; and these last, I have already mentioned to you, consist of *arteries*, which are employed to transmit the blood to the various parts of the body from the heart; and *veins*, which are employed to return it to the heart.

HARRIET.

These vessels, I suppose, are of the same nature, though they differ in some degree in their office.

DR. A.

In that supposition you are much mistaken. The arteries are of a much thicker, firmer, and

more elastic nature than the veins, and are moreover distinguished by their pulsation.

SOPHIA.

The pulse, then, which is felt at the wrist, arises from an artery: but how does it happen, that we do not feel pulses in other parts of the body, as arteries must be very extensively diffused which we see that veins are?

DR. A.

Arteries are in general deep seated, for the purpose of their protection from injury. There are, however, some places, where they are readily felt, and their pulsation even seen, as for instance in the temple, where small branches arise from a trunk which passes up close by the ear. In some other places they may likewise be felt with a little care, as in the whole course of the arm, from the shoulder to the elbow. The force of arterial pulsation may be readily imagined, when I tell you, that the motion of the leg which is to be observed when one leg is placed across the other, arises from the pulsation of an artery in the ham, and which it would be difficult, if not impossible to stop, by any weight which we might employ for the purpose.—The general view of the circulation is, that the heart transmits the blood to the different parts of the body by the arteries,

which is returned by the veins to the heart, to be again circulated. This is called the *greater circulation*; but at the same time it is to be observed, that there is an intermediate, or *lesser circulation*, to which it is also to be subject through the lungs.—The mixture of chyle and lymph enters the veins; and the veins convey the blood to the right side of the heart, from whence it is carried through the lungs. It is then brought back to the left side of the heart, and forthwith transmitted by the arteries all over the body, to be brought back by the veins, and to be continually subject to a repetition of the same career.

HARRIET.

Then there appears to be a sort of double circulation; one side of the heart circulating the blood through the lungs, the other over the body. But I wonder why the lungs should not derive their blood and nourishment in a way similar to other parts of the body, through the medium of the arteries from the left side of the heart.

DR. A.

The nourishment and support of the lungs are effected by means of arteries, in the way which you have suggested; but you must remark, that when blood from the veins is first received into the heart, with the recent addition of chyle and

lymph which have been made to it, it is not fitted for the support of the system; and hence it is, that the lesser circulation takes place.

HARRIET.

Does the blood then differ in different parts of the body? I thought that it had all been alike in nature, as it is in appearance.

DR. A.

But it is not alike, either in nature or appearance; for that which is contained in the arteries, is of a florid red, or scarlet colour; that which is contained in the veins, is of a dark, or modena red; and the former only is fitted for the nutritive purposes of the system.—When the venous blood is received into the heart, it is of a very dark colour. It circulates through the lungs, and it returns florid. It is in this organ, therefore, that it becomes properly, and finally assimilated. It returns back proper blood, is circulated, furnishes the materials for the growth of parts, and for the formation of the various secretions of the body; and after serving these purposes, its nature is changed, it is returned by the veins, of an altered colour and character, and unable further to nourish and support. It receives the addition of fresh materials from the food, is then elaborated in the lungs, and again undergoes the same process.

CHARLES.

Has the change which the blood undergoes in its circulation through the lungs, been ascertained?

DR. A.

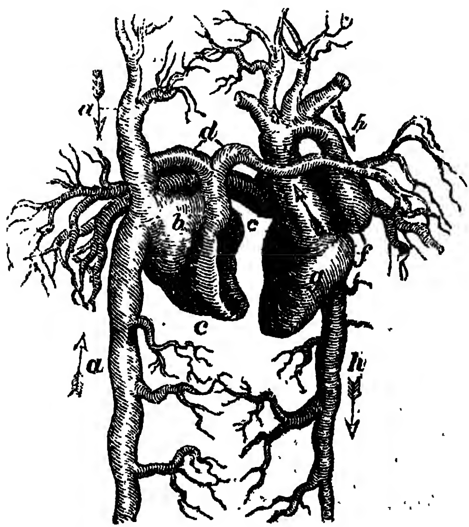
The changes produced in the lungs depend principally on the operation of the air in respiration. This, however, will come under our more particular notice, in considering the lungs, and the functions to which they are subservient. We must now examine the great organ of circulation, the heart.

THE HEART is principally composed of irregular fleshy fibres, of considerable strength. It is lodged in a sort of bag, called the *pericardium*, which usually contains a portion of watery fluid in it, called the water of the pericardium. The heart and lungs are both of them contained in the cavity of the thorax, or chest. This cavity is, as I have stated before, separated from the cavity of the abdomen by the *diaphragm*, which is a muscle capable, by its contraction and expansion, of enlarging or contracting the cavity of the chest. It is so placed as to be concave outwardly: that is, towards the abdomen; and convex inwardly, towards the chest; and has, on this account, been aptly enough compared to the shape of the bottom of a wine bottle, which ascends some distance into the body of the bottle, just as the

diaphragm does into the body of the chest. The chest is divided, from behind forwards, into two parts, by a double membrane called the *mediastinum*, which, however, leaves rather less space on the left side, than the right. The *lungs* fill up the whole of the right side of the chest; but they divide the left with the heart, which occupies a considerable space in the front; as you may observe in the sketch which I shewed you at our last meeting. The *heart* lies in a somewhat oblique position across the chest, its apex or point being towards the ribs, on the left side; while its basis, or broadest part, is higher up, and towards the centre of the chest. It contains within it two cavities, or *ventricles*, one of which is called the *anterior*, or right, and the other, the *posterior*, or left ventricle. It has also at its basis, and communicating with their respective ventricles, two other cavities, called *auricles*, so termed from their resemblance to a dog's ear, one of which is designated by the name of the right, and the other by that of the left auricle. The heart may, therefore, be considered as constituted by the union of four hollow muscles; namely, two ventricles and two auricles, each of them having a power of acting separately on the blood, which passes through them; but the muscular flesh which makes up the ventricles, is very much thicker and stronger than that which constitutes the auricles.

But it is necessary to examine more particularly the mode in which the circulation is carried on through the heart; and in order to make myself more intelligible, I shall suppose this again to be divided into two separate parts, the one, that which transmits the blood through the lungs; the other that which conveys the blood over the body. Each of those parts consists of an auricle and a ventricle. Now the blood which has circulated over the body, is brought back to the heart by an ascending and descending vein, and is poured in a full stream into its right auricle. As soon as the auricle is full, it contracts on its contents, and forces them into the right ventricle. When this becomes distended, it likewise contracts, and pushes the blood throughout the lungs, by means of the pulmonary artery. This is the completion of the first circulation, and in the sketch which I have made, you will see that *aa* designates the ascending and descending vena cava, which unite in transferring their blood to the auricle *b*, which gives it up to the ventricle *c*, and this to the pulmonary artery *d*, and subsequently to the lungs, which ramify into various branches on each side of the sketch. After the blood has circulated through the lungs, and has had those changes produced in it which the lungs are destined to effect, the second circulation commences, by the blood being transmitted through the means of the

pulmonary vein *e* (or rather veins, for there are two from each lung) to the left side of the heart, where it enters the left auricle *f*, which contracts upon it, and forces it into the left ventricle *g*. This, in its turn, when full, contracts, and transfers it to the ascending aorta, or great artery, which is designated by the arrow ascending from the ventricle *g*; and this makes a curve called the arch of the aorta, from which various branches are sent out to supply the head and upper extremities; and descends in the descending aorta *hh*, to be diffused over the remaining parts of the body.



SOPHIA.

How exceedingly interesting is this detail. And I do not despair of understanding it, through the medium of the sketch that you have given us. If the two divisions were brought together, we should have, I suppose, a sketch of the heart as a whole?

DR. A.

Certainly; and for further illustration I shall show you another sketch, in which the heart is exhibited with its two sides joined, or locked into each other; though you will find it rather difficult to comprehend so apparently confused an assemblage of vessels as are here exhibited. In this sketch, 1 1 represent the large veins, the cavæ, answering to *a a* of the former one; 2 2 represent the right and left auricles, answering to *b f*; and having the pulmonary artery answering to *d*, expanding to the lungs on each side, between them; 3 3 are the right and left ventricles, answering to *c g*; and 4 is the aorta, answering to *h h*, the pulmonary artery answ ring to *e* being supposed to be concealed by the auricles.

SOPHIA.

Is the motion of the blood through the heart quickly performed? I suppose the beating of the heart must, in some way, be produced by the action of the auricles and the ventricles.

DR. A.

The beat of the heart evinces the contraction of its ventricles; and as the standard in a healthy adult is about 70 in a minute, you will understand in what a continual and rapid alternation of fulness and emptiness the heart is.

CHARLES.

But as the different parts of the heart act separately, we must only, I suppose, feel the beat

of one particular part at a time; unless, indeed, two movements can go on at once.

DR. A.

And this last is the case. The beat is produced by the forcible contraction of the ventricles, which, taking place at the same instant, forces the blood which is in the right side of the heart, that is, in the right ventricle, into the pulmonary artery, through the lungs; and at the same time the blood, which is in the left side of the heart, that is, in the left ventricle, into the aorta, to be dispersed over the body.

CHARLES.

But then the auricles receive their supply from the veins, just as frequently as the ventricles pass on the blood which has been transmitted to them. Is their action, of passing the blood on to the ventricles, capable of being felt?

DR. A.

The force which they are enabled to exercise, is much less than that of the ventricles; and so is the necessity for the exercise of force; and perhaps an inspection of the plan may afford you a reason for these circumstances.

CHARLES.

The auricles have only to propel the blood into

the adjoining ventricle; while the one ventricle has to transmit it through the lungs, and the other through the whole body.

DR. A.

Certainly; and, therefore, the force exercised, is not sufficient to produce an apparent beat. The action of the respective parts of the heart follow each other in rapid succession, and that of similar parts in each side have an accordance of movement. For instance, the large veins pour in the blood into the right auricles, at the same time that the pulmonary veins pour it into the left. Both auricles contract at the same time, and throw the blood simultaneously into the ventricle of their respective side; and I have already mentioned, that both ventricles act together, and form the beat. In professional language, the action, or contraction of the ventricles of the heart, constitutes its systole; the dilatation its diastole.

CHARLES.

It seems to be singular, that the contractions of the heart should only take place when the auricles and ventricles are full of blood. Is there any particular reason why this effect does not occur before these parts are filled, and thus more frequent pulsations produced?

DR. A.

In all muscles, there is, by the laws of nature, some particular stimulus, or exciting cause, which produces their action. This, with the heart, is the blood; and both the nature of the fluid, and distension produced by it, seem to be necessary to stimulate the muscular fibres to contract. The disposition to contract is so strong in the heart, that it continues in some animals for some time after death; and is readily excited by any mechanical irritation, even when separated from the body. Thus the little heart of a frog will continue its beat, many hours after the death of the animal, and its removal from the body; and the touch of a pointed instrument will restore it after it has ceased.

CHARLES.

As the auricles and ventricles are separate cavities in which the blood is always to go one way; there is, I suppose, some sort of valvular structure, as there is in the lymphatics, to prevent its regurgitation.

DR. A.

This is a beautiful part of the structure of the heart; and one, indeed, which was a principal means of leading the great Harvey to discover the real nature of the circulation; for as he found that there were valves, and that these allowed the passage of a

fluid in one direction only, he was thus led to discover the true principles of the blood's progress through the body. The veins pour, in a continued stream, their blood into the right auricle, forced on by the pressure of the blood behind; but between this auricle and its ventricle, and between its ventricle and the pulmonary artery, there are valves placed, which prevent any regurgitation of blood into the auricle from the ventricle, or into the ventricle from the artery. In the same manner, the blood flows, in a continued stream, from the pulmonary veins into the left auricle, being pressed on by that which is behind it; but between the left auricle and its ventricle, and between its ventricle and the aorta, valves are provided, as in the right side of the heart.

CHARLES.

Valves, I suppose, from their name, have some resemblance to folding doors, which open and shut, for the purpose of admitting or excluding.

DR. A.

Floodgates more nearly resemble them in office, with this difference, that valves, in the animal body, admit the passage of a fluid only one way, and thus preclude regurgitation; but they do this by their own action, without the adjustment which is necessary in floodgates.

SOPHIA.

I do not quite understand how a valve, which will let a fluid pass one particular way, can suffer the auricles or ventricles to get full in the manner that you mention. One would imagine that the blood would pass on through the valve, as soon as it was received into the auricle or ventricle, without remaining till the distension takes place, which excites them to action, unless there was some mode by which they could be kept shut.

DR. A.

There is much justness in your remark; but I must observe, that though the general circumstances relative to the heart and arteries, are very well known, some of the minuter points are still matters of speculation. When the ventricles contract, it is clear that the action of their muscular structure will shut the valves which open between them and the auricles, and thus suffer the blood to accumulate in the auricles; and it is very probable, that the elasticity of the coats, both of the pulmonary artery and the aorta, after passing on the column of blood transmitted through them by the ventricles; and the temporary interruption to its flow, which takes place on the cessation of the action of the ventricles, may give such a disposition to regurgitation, as may shut the valves, and allow the filling of the ventricles for the next impulse.

It is to be remarked, too, that on the relaxation of the arteries, a vacuum is produced, which is supplied by the blood from the auricles, and at the same time favours the shutting of the valves of the ventricles, so as to allow them to get filled.

CHARLES.

But if the contraction of the ventricles will shut the valves between them and the auricles, may not a contraction of the arteries shut the valves between the latter and the ventricles?

DR. A.

It has been a matter of question with some physiologists of late years, whether there is any actual diminution in the calibre of the larger arteries, after the current of blood has been passed through them; and it is thought by many, that the movement of the blood is produced by the action of the ventricles alone; and that the arteries, particularly the large ones, principally perform the part of pipes, to carry it on to the various parts of the body.

CHARLES.

But I thought that the pulse was produced by the swell of the arteries, owing to the increased quantity of blood thrown into them from the heart.

DR. A.

Such was long the prevailing idea; but doubts were thrown upon it by the consideration, that the vascular system must always contain the same quantity of blood in it; inasmuch as the same quantity makes its entrance into the heart from the venal extremity, as leaves it at the arterial extremity. It has likewise been stated, that in circumstances where there has been the power of seeing an artery uncovered, no dilatation or contraction in it were perceptible, though the impulse from the blood which was continually thrown into it from the heart, was distinctly felt on the coats of the artery, when the finger was applied to it. These, however, are minutenesses, which are rather inappropriate to the nature of our general considerations of physiological subjects.

CHARLES.

On this supposition, therefore, I presume, the impression communicated to the tube or pipe, as a solid elastic body, is felt by the finger.

DR. A.

This is thought to be the case, though it is rather difficult, on this hypothesis, to account for the beat being seen; unless, indeed, the mere vibratory motion communicated to the coats of the artery, should be apparent when propagated to the contiguous parts.

HARRIET.

I have often wondered what particular information about diseases the pulse can communicate; and perhaps you can give us a little idea of this, without at all risking our becoming doctors.

DR. A.

Whether the artery may be regarded as actually enlarged during its beat, or as merely communicating an impulse from the heart, the state of the pulse imparts to us a knowledge of the force and rapidity of the circulation, and gives us much other information relative to vascular action, which is important in enabling us to judge of diseases.

HARRIET.

Does the beat at the heart, and the pulsation at the arteries, take place at the same instant of time?

DR. A.

This is commonly represented as the case; but I think you will find, on feeling the beat of the heart with one hand, while, with the other, you feel the artery at the wrist, that they are not quite simultaneous.

HARRIET.

There seems, indeed, to be a very small, though an appreciable interval between them; but it requires great attention to make out this point.

CHARLES.

The heart seems to be a sort of forcing pump, which possesses a power that is necessary for carrying the blood over the body.

DR. A.

The relaxation and expansion of the ventricles, may be considered as producing what is equivalent to the vacuum formed in the pump, by means of which the water is raised; and the contraction of the ventricles acts the part of the depression of the piston; while in both cases there is a set of valves, which open in one direction only.

CHARLES.

The muscular power of the heart must be exceedingly great, since it can exercise the faculty of compression, to the extent of emptying its vessels completely, at every pulsation.

DR. A.

It is the most powerful muscular structure of the body, and it owes its great extent and force of contraction, to the particular disposition of the muscular fibres which form the ventricles. The right ventricle has to do no more than circulate the blood through the lungs; but the left has appropriated to it, the office of transmitting it over the whole system. It is therefore much thicker and stronger than the right; and possesses a very

peculiar structure to give it greater power; being constituted of two sets of fibres, disposed in strata, and surrounding the ventricle in a spiral form, the spiral disposition of the strata being in opposite directions. In this way, it is clear, that longer fibres can be employed, and that a smaller contraction of each set will be necessary, than under a different distribution.

CHARLES.

Have any calculations been made as to the quantity of blood which the body contains, and the celerity of its movement through the heart? Since the whole of the blood of the body passes through the heart, it must, I suppose, repeat its progress very frequently during the day.

DR. A.

It has been considered that the quantity of blood contained in the body, amounts to between 30 and 40 pounds; and that about two ounces pass on from the heart at each pulsation. In this way, at 70 pulsations in a minute, 140 ounces will pass through the heart in a minute, or 9000 ounces in an hour. Hence the whole quantity of blood contained in the body, supposing it to be 35 pounds, will pass through the circulation in about three minutes, or about 20 times in an hour, or 480 times in a day.

HARRIET.

What a continual state of flux and reflux, of ebbing and flowing, takes place in the system; and this, too, when the circulation is not hurried; for I presume that in running, or taking any other violent exercise, the circulation is still more rapid.

DR. A.

Unquestionably; and other phenomena produced in consequence, as increased perspiration, and augmented temperature, which will afterwards come under consideration.—When the contraction of the left ventricle takes place, the blood, as I have already mentioned, is forced into the aorta, or great artery. This consists of two divisions; one of which is termed the aorta ascendens, or ascending aorta, the other, the aorta descendens, or descending aorta; and between them is the curve called the arch, as you would observe in the sketches which I have shown you. From the arch of the aorta, the vessels, as I stated to you, pass off, which supply the head and upper extremities; while the descending aorta transmits vessels which are appropriated to the viscera of the abdomen, and all the neighbouring parts, and which at last terminate in those that supply the lower extremities.

SOPHIA.

Is there any regularity in the disposition and appropriation of these vessels?

DR. A.

There are occasional varieties, but in general there is great regularity in their distribution; so that the anatomist knows where to find a particular vessel, either within any of the cavities, or more superficially; and as they have all of them names, his researches may be conducted with great precision. The names, I may observe, are generally given to the artery from its supposed use, or from the part which it is intended to supply.

An *artery*, as I have already mentioned, is a thick, firm, elastic tube, which, when cut, retracts. It consists of three coats, the external, made of firmly condensed cellular substance, of a white colour, and fixed to contiguous parts; the middle, which has been supposed to consist of muscular fibres, though much difference of opinion has taken place on this subject; and the inner, which is a smooth, thin, dense, and transparent membrane. The thickness of the coats, and their proportion to each other, differ according to the calibre of the artery. In the large arteries, the existence of a muscular coat may be considered as somewhat equivocal; but it is hardly, I think, to be questioned in the smaller.—Both arteries and veins are nourished by blood-vessels, and are also supplied with nerves and absorbents, like other part of the body. The blood is first forced into the arteries by the powerful action of the left ventricle,

and stream after stream following in quick succession, the column of blood is propelled on to the minutest ramifications. The motion, however, though principally depending on the heart, is promoted by the elasticity of the large, and the muscular power of the small arteries.

SOPHIA.

The quickness of the circulation must, I suppose, be easily affected; for exercise seems to give one a sensation of throbbing all over the body.

DR. A.

Not only does exercise accelerate the circulation, but, with weak people especially, various other circumstances; such as sudden alarm, and many other affections of the mind; the act of digestion; and even a sudden change of posture. The circulation becomes slower as life advances, being with infants as high as 120 or 130 beats in a minute; and gradually falling to 70 or 75, which is about the standard of adult age. The blood is, as I have mentioned, carried over the body by the arteries, and brought back by the veins. The change of the one vessel into the other takes place at the extremity of each, where, from their minuteness, they are termed *capillaries*, or no larger than hairs, though they are still capable of carrying red blood.

SOPHIA.

What do you mean by the term red blood? Is it ever of any other colour?

DR. A.

When blood is taken from a vein, it is fluid; but it soon coagulates, and divides into two parts, the crassamentum, or solid red part, and the serum, or fluid part, which is of a yellowish tinge, and transparent. The crassamentum owes its redness to what are called red particles, which, though very minute, being not more than the $\frac{1}{5000}$th part of an inch in diameter, require vessels of a certain size to admit them. Now some parts of the body, as the white of the eye, are supplied with colourless blood, because the vessels are two small to admit the red particles; but as soon as these vessels become larger from any cause, as from inflammation, then they become apparent, because they are able to admit the red particles, which make them visible.

HARRIET.

But how are you enabled to ascertain this termination of arteries into veins, since they are both of them so exceedingly minute?

DR. A.

If we tie an artery, or press on it, we prevent the blood from flowing on to the extremities, which

shows that its course is thitherward. If we do the same to a vein, we prevent it from carrying on the blood in a reverse direction. On tying up an arm for bleeding, or merely on pressing it tight, we find that the veins enlarge below the compressed part, which shows that the blood is returning to the heart; but a compression of the artery would interrupt the passage of the blood from the arteries to the veins; hence, in bleeding, this is to be avoided. The veins of the extremities, likewise, have valves, which prevent the progress of the blood, except in a direction to the heart.

CHARLES.

Can any sort of fluid be thrown from the arteries into the veins, in order to demonstrate, still more completely, the passage of the blood from the one into the other?

DR. A.

Anatomists have occasionally succeeded in throwing injections from the arteries into the veins; but, in general, the most delicate and subtle injections are unable to pass through the minute vessels which form the extremities of arteries and veins, though they are capable of distending either [illegible] the other in such a way as to make the [illegible] eye, or any other part which is usually colourless, quite red, when a red injection is employed.

CHARLES.

We know, by bleeding, that the wounds of veins will heal; but, as you mention that arteries are of an elastic nature, and retract when divided, any injury to them must be of a very formidable nature, and any wound very difficultly healed.

DR. A.

Unquestionably; and hence nature has looked to their safety, by giving them as deep and protected a situation as possible. When they are wounded, or divided, however, they do not heal, but are obliged to be tied up, if large, —that is, a ligature put round them; or, if small, they contract of themselves, so as to resist the passage of the blood through them.

CHARLES.

But then, does not this operation cut off the passage of the blood to the parts beneath, so as to prevent their nourishment, and therefore to occasion their death?

DR. A.

This would be the case, except for a very wise provision of nature, which has effected a general connection of the various arteries, by means of what is called *anastomosis*. In order to understand this, you must consider that arteries send out, in their

course, certain large branches, which are divided into smaller and smaller ones, like the branches of a tree, until they terminate in the most minute. Now according to this structure, it is clear, that if you cut off the communication between the branches and the trunk, you would cut off the supply of the blood. But then the superior branches, which go off from an artery or its subdivisions, send off some branches which unite with others that are transmitted from branches below them. If the artery should, therefore, be divided in an intermediate space, the connection is kept up, between the vessel above and the parts below, by means of these anastomosing, or communicating branches, and thus any inconvenience avoided.

HARRIET.

This is a very beautiful provision of nature; but are not the communicating branches so very minute, as not to be adequate to supply the parts below?

DR. A.

As soon as a large arterial trunk is tied, all pulsation in the parts below ceases; and, in a few hours, the warmth of the part is often a good deal diminished. Nature, however, is not idle under these circumstances: the column of blood, forced from above, and interrupted in its usual progress, is projected into the lateral vessels, and gradually

finds its way through the communicating, or anastomosing ones, which, by degrees, enlarge to a sufficient size to admit of the usual circulation being carried on. Then the heat is restored, and the pulsation returns in the vessels beneath. This is one of the most important provisions in the animal economy, and is that on which the success of so many operations depends; for whenever surgeons operate, they may be always sure, that if they have occasion to tie a vessel, and thus cut off the immediate supply of blood to a part, nature will produce an abundant supply from above. This was a matter formerly in doubt, and therefore surgeons tied vessels with fear and trembling as to the result; but so general is anastomosis, that Sir Astley Cooper, in order to establish its existence, in even the largest vessels, once tied, or, as surgeons term it, took up, the aorta of a dog, and found that anastomosing branches supplied the parts beneath, even after so formidable an operation. — I may just mention to you, that a very scientific operation was devised by Mr. Hunter, from a knowledge of this principle, in a very serious disease, that of popliteal aneurism. This consists in an enlargement of the artery at the ham, which, if suffered to go on, would most likely in time give way, and occasion death. His object was to cut off the supply of blood from it; and for this purpose, he laid bare the artery at the

middle of the thigh, where it is pretty readily accessible, and tied it. He thus cut off the supply of blood to the tumour in the ham, knowing that branches sent off above the tied part, would unite with others below the tumour, and thus supply the leg and foot as well as ever. In this he was not disappointed; and the operation, with some modifications, as that of tying the artery in two places, and dividing in the intermediate space, is one of the most creditable in modern surgery. In both these cases, the extremities of the vessels become glued together, by the effusion of a portion of the coagulable part of the blood, and are soon able to resist the pressure of the column against them.

CHARLES.

You spoke of the blood being carried through the body principally by the action of the heart, but partly, also, by the elasticity, and the muscular power of the arteries. But then in what way does its return take place? for the minute ramifications of the arteries, previous to their termination in veins, would, I should imagine, take away a great deal of the original impulse, and hardly admit of a sufficient quantity remaining for the return of the blood.

DR. A.

As there are continual successive columns of blood sent from the heart along the arteries, those

are necessarily forced into the veins, as the only means of egress; but then, as the blood comes so gradually into the latter, there is no pulsation in them, as in the arteries; and their coats are, moreover, much thinner and more distensible, and want the firmness and elasticity which those of the arteries possess, and to which the pulse is in a great degree owing. It has been thought, likewise, that there is some degree of active force employed by the coats of the vein itself, in passing on the blood, though this is less certain. The motion of the blood in the veins is, however, much more difficultly effected than in the arteries; and hence nature has adopted various devices for the purpose of increasing it. The branches of veins are, together, of greater diameter than the trunks, which is the reverse in the arteries; and hence the blood will flow to the heart in a space gradually becoming narrower, and have its rapidity, therefore, progressively increased. Veins, likewise, have valves in various parts of the body, by means of which any retrogression is avoided, and therefore the ground which has been got maintained: they are more numerous than arteries, and have frequent communications with each other, in every part of their course; and they are so dispersed among the muscles, as to receive a certain propulsion from their action.

CHARLES.

The circumstances which you have now mentioned, relative to the veins, in addition to those which you stated on the mechanism of the heart, seem to make the proofs of the circulation exceedingly conclusive.

DR. A.

The course of the circulation is likewise proved by the transfusion of blood from one animal to another, which has been effected by fixing a tube to the artery of one, and connecting it with the vein of another. In this case, if another vein is opened in the animal which receives the blood, so as to make room for the admission of the fresh blood, an entire change in the mass may be effected.

SOPHIA.

And could this extraordinary operation be performed with safety to the animal?

DR. A.

Many of the early experiments on this subject were unsuccessful; but it has been discovered by modern physiologists, that transfusion can only be practised with safety from one animal to another of the same species. The utility of a process of this kind requires, however, greater experience to ascertain it than has yet been obtained on the subject.

SOPHIA.

It would appear, then, that this practice might be employed to communicate the exuberant health of one animal to another; though it would rather be at a dear rate, as the animal which parted with its blood, must be as much injured, as the other would be invigorated.

DR. A.

This does not follow; for a healthy animal can part with a good deal of blood without injury.—In great depletion from loss of blood, dogs have been very speedily restored by transfusing into them the blood of other dogs; and one case has occurred in the human subject, in which the injection, by a syringe, of blood from the vein of a healthy person, immediately on its reception into a basin, was attended with considerable temporary advantage.—The microscope has been employed to observe the circulation in particular parts of some animals, which have considerable clearness of skin, as the web of the frog's foot; and I expect that you will be able to witness this interesting phenomenon, by inspecting, in my microscope, the foot of a little prisoner that I have obtained for the purpose. If one of you will hold it, I shall place the web in the field of the microscope; and on adjusting the instrument to your eye, you will observe the circulation distinctly.

HARRIET.

It is very distinct, and rapid, and the globules of the blood are perfectly apparent; but it is difficult to make out the direction in which they move.

DR. A.

A very practised eye is required for observations of this kind.—The circumstances which have been mentioned as favouring the motion of the blood in the veins, have, by many, been regarded as insufficient for the purpose; and some experiments have lately been made, from which it is inferred, that during inspiration, when air is admitted into the lungs, the fluids communicating with its vessels will press into them from the vacuum made by their distension; and hence it is concluded, that the rush which must take place to all parts of the venous system, in order to supply the vacuum in consequence of atmospheric pressure on the surface of the body, must materially tend to support the motion of the venous blood. The same principle is applied to the motion of the chyle in the lymphatic system, in consequence of the connection of the thoracic duct with the vein into which the chyle is poured.

HARRIET.

You mentioned that only the coloured part of the blood returns by the veins: — what becomes of

the part which is without the red globules, or is colourless?

DR. A.

A part of it returns by minuter veins, which refuse entrance except to the colourless portion of the blood; and these soon unite with the larger ones. Another part is carried to various glands, or is otherwise employed, either in affording materials for producing various secretions, or in supporting, or regenerating the different parts of the body; while another is thrown by open-mouthed vessels, either into the various cavities of the body, when moisture is required, or to the surface, to be carried off by perspiration; and you will recollect what I remarked on the subject of secretion, and the action of the absorbents, that a certain balance is kept up between the process which forms, supports, or renews, and that which carries off, so as to preserve the body in a state of health and fitness for its various functions.—The circulation of a nutritive fluid through a heart and blood-vessels, is the mode by which most animals have their vital functions carried on; but there are many varieties in the method by which this operation is accomplished, depending on the peculiar nature of the animal, and the medium which it inhabits.—The blood in most animals possesses the peculiar colour and appearance by which it is usually known; and

such are therefore called *red-blooded animals*, and consist of the mammalia, birds, the amphibia, and fishes; but there are others of a lower description, as the mollusca, insects, and worms, in which the blood is colourless; and such animals are therefore called *white-blooded*. In most of them the circulating system is very obscure, and but little known. The red-blooded animals are divided into the *warm-blooded* and *cold-blooded*, according as their temperature is uniformly much above that of the atmosphere, or as it follows that of the medium in which the animals may live, as air or water. The mammalia and birds are among the first description; for whatever the temperature of the air may be in which they live, their bodies uniformly maintain the same standard. Amphibious animals and fish are among the second. Now we shall find that the respiration of animals has a great deal to do with the production of animal heat, and that, when from any circumstances the respiration is liable to be interrupted, as in the amphibious animals, nature obviates, by a peculiar structure, the necessity for the blood passing through the lungs, as in the mammalia and birds, though at the expence of that production of heat which is so characteristic of the two former classes. This is done by means of what we may call a *single heart*; for the blood, when received from the veins into the auricle and ventricle, instead of passing through the lungs, as

in the breathing and warm-blooded animals, goes off in a vessel which divides into two branches, one of which supplies the body generally, and another is diffused over the lungs, to carry back a certain portion only of that influence, which the lungs are intended to supply.

HARRIET.

Then the completeness of the exposure of the blood to the influence of the lungs, is the great ground of distinction between those animals?

DR. A.

Certainly.

HARRIET.

But there must be a considerable difference between the nature of such animals, since the one set of them can live so much without air, while the other would be suffocated by its interruption for but a very short time.

DR. A.

The difference is considerable; for there is a dulness and want of vigour and vivacity in the cold-blooded animals, which seems to be connected with their conformation, and with the want of the vivifying influence of the air upon them. There is likewise a remarkable tenacity of life, and a power of contraction in their muscles very long after life has ceased, of which I have men-

tioned a remarkable instance in the heart of the frog.

CHARLES.

I have heard of some defects in the circulation through the human heart, which evinced themselves in some peculiar appearances of body.

DR. A.

The heart is subject to many diseases; to increased magnitude; to want of power; to obstruction in the passages from one part to another, to imperfection in the valvular structure, or in the structure of the vessels themselves, all which produce symptoms more or less well marked, and often of a dangerous and alarming description. But there is one imperfection, which is that, perhaps, of which you may have heard, which assimilates the heart to that of the amphibious animals:—it is when there is a communication between the ventricles which allows a part of the blood to escape into the circulation, without passing through the lungs. In this case, the colour of the skin is purple, and the unfortunate person is subject to various distressing symptoms, and has a great defect of general energy.—I may remark, that animals before birth, have a communication between the ventricles, which is necessary on account of their lungs not acting at that time. After birth, when the animal breathes, this com-

munication becomes unnecessary, and closes. It is when it does not close, that the circumstances which I have just mentioned occur.

CHARLES.

You have explained to us very distinctly the peculiarities of the circulation in amphibious animals, which seem to be in a certain degree independent of respiration: but how is it with the other order of cold-blooded animals having red blood, *fishes*; for in them there must be a provision for doing without respiration entirely, since they live wholly in water?

DR. A.

They have not lungs, and they do not live in air; but they dwell in an element which is charged with air, and have an apparatus for availing themselves of it without respiration; for their hearts are single, receiving in their auricle the blood from the veins, passing it on to the ventricle, and the ventricle into the great artery. Then, however, the blood, instead of going on to the general circulation, passes through the *gills*, which are composed of a delicate membrane, very widely expanded, and admitting of a very minute division of vessels over its surface. The blood, in these minute vessels, is exposed to the air contained in the water, and hence has the necessary salutary change produced upon it. It unites in a trunk,

which, like the aorta in the mammalia, carries it into the various parts of the body.

The next subject of our consideration is RESPIRATION, or that particular function which treats of the changes which the blood undergoes in the lungs. This will form the employment of our next meeting; but before I take leave of circulation, it is necessary to notice a singular appropriation which nature has made of some of the veins of the abdomen. Those which bring the blood back from the stomach, the spleen, the sweetbread, the intestines, and omentum, instead of joining the large vein (the vena cava), and transmitting their contents by this channel immediately into the right side of the heart, unite in one trunk, which divides into various ramifications in the liver, and thus imitates in some measure the distribution of an artery. The blood is brought back by veins, which join the vena cava and thus it goes on to the heart, as it might have been expected to do, from the general analogy of the circulation, without the intermedium of circulation through the liver. The route which the abdominal blood thus takes, is connected with the process of secreting the bile from that organ.

CONVERSATION XVIII.

ON RESPIRATION.

DR. A.

In framing the organs of respiration in the higher orders of animals, nature has had two great objects in view; the one, that of forming the voice; the other, that of completing, as I have already stated to be necessary, the changes which are requisite for adapting the blood to the functions which it is intended to perform in the animal economy.

The organs of respiration, properly so called, consist of the LARYNX, the TRACHEA, or WINDPIPE, and the LUNGS. The larynx is the projecting part which you can see and feel at the upper part of the throat. It is the commencement of the windpipe, and is the organ in which the voice is formed. The windpipe is the tube which is connected with this, and is divided first into two, and then into smaller branches, called bronchiæ, which at last terminate in small cells, that form the minute structure of the lungs.

CHARLES.

These organs may therefore be considered as nothing more than subservient, or preparatory, to the more immediate functions of respiration.

DR. A.

Nothing more; and they are to a certain degree passive, as is indeed the whole substance of the lungs; but there are other parts which are necessary for carrying on the mechanical process of admitting and ejecting the air from the lungs, and these in man and quadrupeds are principally a very large and strong muscle called the diaphragm, which I have already mentioned to you, as separating the abdomen from the thorax: and various small muscles which lie between the ribs.

SOPHIA.

I do not understand what you mean when you say that the windpipe and lungs are passive organs; they surely are actively employed both in receiving air into them, and in forcing it out.

DR. A.

No more than the barrel of an air-pump is an active organ in working it, or the cylinder of a common pump in elevating the water. When you work a pump, you elevate a piston, which would leave a vacuum but for the air or water which

rushes in to supply it. On depressing the piston, you force out the air or water, and thus prepare for a repetition of the process. The lungs accurately fill every unoccupied part of the chest; and it is by diminishing the cavity which contains them, that the air with which they are filled is forced out.

HARRIET.

Is there any particular advantage gained, by not employing muscular contraction in the lungs themselves, to force out the air from them?

DR. A.

In respiration, it is necessary that the blood should be exposed extensively, and in the most divided state possible, to the influence of the air, which renders a secure position necessary, and precludes the firm structure of strong muscles.— The mechanism employed in dilatation and expansion is exceedingly simple; for the contraction of the diaphragm forces down the abdominal viscera, and thus enlarges the cavity of the chest downwards, while the action of the muscles between the ribs raises up the latter, and produces an expansion in another direction. The necessary effect of this increase of size is, that the air rushes in to the windpipe, to supply the void which would otherwise occur; and when the diaphragm and

intercostal muscles cease to act, and become relaxed, the elasticity of the cartilaginous parts of the chest, but more particularly the tendency of the muscles of the abdomen to recover themselves, after being pressed down by the contraction of the diaphragm, have the effect of diminishing the capacity of the chest, and of thus forcing out the air from the lungs, which has been received by inspiration. The alternate dilatation and contraction of the chest which thus takes place, constitutes the act of respiration, which, as I mentioned to you some time since, is of a mixed nature, being partly dependent on the will, and partly independent of it.

HARRIET.

We certainly have the power of regulating our breathing when we exercise sufficient attention; but the necessity of carrying on the alternation seems to be quite incontrollable.

DR. A.

It is fortunate that it is so, for we should be but bad judges of the continual wants of the system; and nature wisely provides for our health, by giving the sense of suffocation to ensure a constant supply of air, and the feelings of hunger and thirst to guarantee to us food and drink.—The *larynx* [illegible] up of a considerable number of cartilages

or gristles united together, forming an irregular sort of tube, open at both ends, and capable, by means of the numerous muscles which it possesses, of those minute varieties of contraction, or enlargement, which are necessary for producing the diversified modulations of sound of which it is capable. It is fixed as a sort of capital on the *windpipe*, which is composed of numerous cartilaginous rings, which are incomplete for about a quarter of an inch at their hinder part. This interval, as well as that which is between the rings, is filled up, partly by transverse and longitudinal muscular fibres, and partly by a firm and ligamentous cellular membrane; and the interior of the whole is covered with a soft mucous lining, which secretes a fluid intended to keep it continually moist. The cartilaginous rings continue for some time after the division of the trachea, but at length disappear in the substance of the lungs.

The LUNGS themselves are of a light, spongy, but tenacious texture, one in each cavity of the chest, capable of swimming in water, separable into subdivisions called lobes, and covered with a membrane called the *pleura*, which doubles back, and lines the cavities of the chest, just as the peritoneum does the cavity of the abdomen. The lungs are very largely supplied with blood-vessels, of which some appear to be destined for the nourish-

ment of the organ; but by far the principal part convey the blood from the right side of the heart, in order that it may, after minute division, and diffusion over the air-cells, be exposed to the influence of the external air, and be carried back to the heart in a proper state for nourishing the body.'

CHARLES.

The secretion which you mention as covering the interior of the windpipe is, I suppose, affected during a cold, or any other disease of this passage.

DR. A.

A common cold produces a slight inflammation of the passage, and is attended at first with a diminished secretion; but is carried off by an increase of it, which is a very ordinary mode adopted by nature for removing the inflammation of passages. When the inflammation goes on to a much greater extent, it produces the formidable disease of croup, which is occasionally attended with the formation of a new membrane in the windpipe, from the pouring out of coagulable matter into it, as an effect of severe inflammation. Sometimes the larynx itself is the principal seat of inflammation, and the symptoms are then, as well as in the former case, of the most severe kind.

HARRIET.

Consumption, I presume, is something more than a severe cold; for I have often been surprised to find, that some people recover from severe and frequent colds without much difficulty: and yet others become consumptive, and are carried off at longer or shorter intervals; which makes me think there must be some difference in nature between a cold, however severe it may be, and consumption.

DR. A.

You are quite right; there is an important difference; for colds, however severe, only for the most part excite the tendency to consumption, which already exists in the habit. Consumption consists in an ulceration of a part of the lungs: and this process most generally occurs in a sort of small scrophulous tumors, called tubercles, which may long exist and be harmless; but which, when inflamed by colds, ulcerate, produce a hectic fever, a loss of flesh and strength, and all those symptoms which occur in that serious malady. Sometimes a blood-vessel gives way, and if the wound does not thoroughly heal, an ulcer is produced in consequence; and sometimes an abscess or vomica occurs, from the effect of inflammation, which ends in a similar way.

CHARLES.

The laxity of the substance of the lungs, and their being in continual action, must encourage disease in them very much.

DR. A.

Unquestionably so; for the one facilitates the spreading of disease, while the other prevents the possibility of lying to, for the purpose of waiting for recovery.

CHARLES.

It seems, indeed, extraordinary, that the functions which you mention as being performed by the lungs on the blood, should go on during a severe state of disease in that organ.

DR. A.

They go on less perfectly, as is occasionally indicated by the livid appearance of the lips, countenance, or extremities, and also by the hurry of the circulation; the same quantity of blood having to pass through a less space, than when the lungs are healthy. —But it is time now to give you some account of the particular action which takes place on the blood in the lungs, and to which all the other parts of this function are subservient. The blood which passes from the right side of the heart into the lungs, is, as I have mentioned to you, of a dark or Modena red co-

lour. After circulating through the lungs, it becomes of a florid red, and has then been rendered fit for nutrition, and for the other functions which it is intended by nature to exercise. In this progression through the lungs, it has been freely exposed to the air of the atmosphere, which is continually received and thrown out, by the alternate actions of inspiration and expiration.

HARRIET.

Then it may be supposed that the air of the atmosphere is in some way changed by respiration, since it is by its agency that the nature of the blood is altered in the lungs.

DR. A.

Atmospheric air, as you may recollect, is composed of about 21 parts by measure of oxygen, or the pure respirable part; and 79 parts of azote, or the unrespirable part, with a small portion, not exceeding 2 per cent, of carbonic acid gas. When an animal is confined in a certain quantity of atmospheric air, a part of the oxygen disappears, and an augmented quantity of carbonic acid gas is found to have been produced.

CHARLES.

This, then, I presume, arises from the carbon of the body uniting with the oxygen of the atmospheric air, and forming carbonic acid gas.

DR. A.

Certainly.

CHARLES.

But then is the whole oxygen which the air contains in it, employed in the formation of the carbonic acid gas, which is found to exist in air that has been breathed?

DR. A.

When dark blood is exposed, out of the body, to the action of oxygen gas, it becomes florid; and hence physiologists concluded, that a portion of it was absorbed by the blood, and produced this change. At the same time as it was found, that carbonic acid gas was formed during respiration, it was considered as likely, that a portion of the oxygen was employed in uniting with the carbon of the blood, and thus forming carbonic acid gas, which, you know, is plentifully produced during respiration in crowded assemblies. The process appeared to be therefore a compound one; but some chemists of great accuracy made it exceedingly probable, that the whole of the oxygen which the atmospheric air lost in respiration, was employed in the formation of the carbonic acid gas which was produced during that process.

SOPHIA.

But how is it possible to conduct such experiments with accuracy? Is an animal confined in a certain known portion of air, and the nature of it examined after respiration?

DR. A.

Assuredly. If a small animal, as a guinea-pig, is placed in a proper apparatus, in a certain quantity of atmospheric air, the weight of the air, and its precise nature, may be accurately determined after the experiment.—Now it would appear, from the results of some late experiments of Dr. Edwards, that a greater proportion of oxygen disappears, than is necessary to form the carbonic acid generated: and that the original supposition is, therefore, the more correct one; namely, that the disappearance of oxygen is occasioned, in part, from its being employed in the formation of carbonic acid gas, by uniting during respiration with the carbon of the blood; but that it arises in some degree, likewise, from its absorption by the mass of blood, in order to produce further, though unknown effects, in the animal economy.

CHARLES.

In the production of carbonic acid gas in the lungs, is the carbon brought to the lungs in the veins, so as to be ready for uniting with the

oxygen afforded by the air, and thus for immediately forming carbonic acid gas?

DR. A.

This is a point which has occasioned much controversy, and which it is very difficult to ascertain. It was supposed by some, that the veins came to the lungs charged with carbon, in a very divided state; and that this carbon was parted with, when oxygen was received into them by respiration, and thus formed carbonic acid gas in the way which you suggest. But then it has been found, that carbonic acid gas is emitted from the lungs, even if oxygen is not received into them; as in cases where animals have been made to respire some other gases, as hydrogen, when there was no oxygen contained in it.

SOPHIA.

I cannot conceive how experiments of this kind can be made, without the destruction of the animal; or even at all, since the proper function of respiration requires that oxygen should be a part of the air inspired.

DR. A.

Some of the lower animals, as frogs and snails, are less dependent on the immediate supply of pure air to the lungs, than the mammalia and birds; and hence, for a short time, experiments can be made on them, without difficulty or incon-

venience. Kittens, too, for a few minutes after birth, before they have been accustomed to the action of atmospheric air, can respire pure hydrogen; and, in all these cases, carbonic acid gas was found to be produced without the contact of oxygen in the lungs; and it is, therefore, clear, that it must have been extricated from the blood. This circumstance, and some others, render it probable that the oxygen is absorbed by the lungs, and unites in the course of the circulation with carbon, forming carbonic acid gas.—There is a singular circumstance attending the action of the lungs in the production of carbonic acid gas, which is, that the quantity varies, not only in different individuals, but in the same individual at different times of the day, and at different periods of life. The greatest production, 4.1 per cent. Dr. Prout found, is between 11 in the forenoon and one in the afternoon; and the smallest, 3.3 per cent. between half-past eight in the evening and half-past three in the morning; the quantity gradually rising to the highest production, and descending to the lowest. In summer, and in young animals, the quantity of carbonic acid gas formed, is less than in winter, and in the older. There has likewise been found to be a singular difference in the quantity of oxygen which is absorbed at different times, beyond that which is accounted for by the carbonic acid gas formed.

CHARLES.

You have spoken, hitherto, only of the changes which oxygen gas undergoes in respiration. Does the other component part of atmospheric air, the azotic gas, undergo no alteration during this process? Or are we to regard it merely as a diluent for the oxygen?

DR. A.

Experiments on the subject of respiration are of so nice a description, and are liable to so many causes of inaccuracy, that it is not to be wondered, that many difficulties arise in the prosecution of inquiries into its precise nature. It was generally considered that the azote remained unaffected by respiration; but some late observations have shown, that there is sometimes a disappearance, and occasionally even a slight increase in the quantity of azote existing in air after expiration. It seems exceedingly likely, as I remarked on the subject of digestion, that considering the quantity of azote which composes the flesh of animals, and its absence, or paucity, in a considerable portion of the food which they employ, there should be some means of compensating for the want of supply of this important substance by food, in its power of absorption from the atmosphere. There would appear, therefore, to be a power of exhaling, or absorbing azote, according to the exigencies of the system.

HARRIET.

Strangling, and exposure to impure air, operate, I suppose, by cutting off a supply of oxygen from the lungs.

DR. A.

When air is deprived of its oxygen, it ceases to be fit for supporting combustion and animal life; but then there is something positively injurious in the effect of carbonic acid gas, which does not attach to azote; and if the carbonic acid gas produced by respiration, is removed from the air in which an animal is confined, it will live longer than if this were not the case. A fermenting vat, which, you know, is full of carbonic acid gas, produces, almost instantaneously, a deleterious influence on the body, which would very soon terminate in death. Hanging and drowning both operate by withdrawing the necessary supply of atmospheric air, and therefore of oxygen, from the lungs; and the means of resuscitation consist, in a most important degree, in restoring it.

HARRIET.

But is there not, in drowning, a large quantity of water swallowed, which is to be got quit of before the patient has any chance of recovery?

DR. A.

This is only a vulgar idea; and instead of turning an unfortunate person upside down, with a

view that the water supposed to be taken in may be dislodged, we ought sedulously to aim at restoring the circulation, by means of warmth and friction; and the respiration, by means of inflation of the lungs, and imitation of the action of respiration.—The lungs not only require a regular supply of pure air, in order to carry on their functions, but also air of a certain density; and hence, in ascending very high mountains, a great inaptitude for bodily exertion, and incapacity for continuing it long, has been experienced in a very remarkable manner. It is to be remarked, however, that travellers have differed a good deal in the description of their sensations in very elevated regions; and that some do not appear to have suffered more inconvenience, than might be supposed to be produced by the fatigue of such a journey.

CHARLES.

It seems to be very singular, that air should have the power of being taken up by the blood, through the blood-vessels in which it circulates in the lungs; for it does not appear that there can be any actual contact between the air and the blood.

DR. A.

Dr. Priestley found that such is the power of absorption, that if venous blood is exposed to

oxygen contained in a moistened bladder, it would become of a florid red, notwithstanding the intervention of the bladder. Now, in the lungs, the blood-vessels are divided very minutely over the air-cells, which freely receive the air, and communicate with each other; but the coats of these cells are very much thinner than the bladder employed in the experiments which I have now mentioned; and there is, therefore, no difficulty in the transmission of the influence of air through them.

CHARLES.

When we consider the frequency of respiration, and the large dimensions of the chest, the quantity of air necessary for the respiration of a single person must be very considerable. Have any calculations been made upon this subject?

DR. A.

The quantity of air taken in at each inspiration, as well as the amount of what the lungs are capable of containing, are subjects on which physiologists have differed exceedingly. It would appear, however, that about forty cubic inches of air are taken in at an ordinary inspiration; and that the whole lungs, in their ordinary state of expansion after respiration, contain about 330 cubic inches. An eighth part is therefore changed by each respiration; and if we suppose that we

respire sixteen times in a minute, we shall respire, during the twenty-four hours, 921,600 cubic inches, or 591 cubic feet of air.

SOPHIA.

What an immense consumption of oxygen is thus produced. It seems to be very extraordinary, indeed, that considering the prodigious demands on the atmosphere, of the many millions of human beings who inhabit the earth, and of the countless numbers of animals which require a constant supply of air, the oxygen should not be consumed, and the air itself contaminated.

DR. A.

Nature has wisely provided for the removal of what is noxious, from air, and for the supply of what is wholesome. Carbonic acid gas, which animals so copiously produce in respiration, and which likewise originates from fermentation and combustion, is capable of being absorbed by water It is also, in certain circumstances, taken in by plants, of which it forms a part of the food, so that there is no danger of any deleterious superabundance. Plants, likewise, when exposed to the rays of the sun, exhale oxygen, which seems to arise from the decomposition of the absorbed carbonic acid gas, the carbon forming a part of the substance of the plant, and the oxygen which

had been united with it, being thrown out. From these causes, and from the various decompositions and new combinations which the decay of animal and vegetable bodies, and the formation of new ones, afford; from the immense extent and volume of the atmosphere; the connection which all the parts of it have with each other; and the ready and continual mixture of its different parts by means of winds, and the various currents which heat and cold produce; this immensity of fluid with which the earth is in every direction surrounded, always preserves the same proportion of its component parts, whether in cities, or in the country; on hills or in valleys; at sea, or on land.

HARRIET.

Is it then merely a vulgar error that there is bad and good air? It would be very difficult to convince mankind of this being the case.

DR. A.

I have not said that there is no such thing as good and bad air; or that there is no difference between the air of one place and another. I have only stated that no difference has been found in the proportions of the component parts of atmospheric air, under any variety of position; meaning, of course, to imply, as far as can be ascertained by chemical analysis.

SOPHIA.

But would you take, for examples most strongly opposed to each other, the confined air of a crowded lane, or court, loaded with unpleasant and injurious exhalations, and the fresh breezes of the ocean, diffusing health and cheerfulness on every side?

DR. A.

Certainly, provided you allow a free communication with the atmosphere; for the respiration of many persons in a certain limited space, will make a considerable difference in the state of the air of a room for the time. It is, however, to be remarked, that chemistry can only go a short way in ascertaining very palpable, though minute, differences in the nature of air. Odours, for instance, cannot be detected by chemical means; and the effluvia which emanate from the body, and give rise to various diseases, elude all our endeavours to ascertain their physical nature. When such is the case, there is no wonder that the nice differences between the air of towns, and the country, should only be discoverable by their effects on the human body. These effects are, however, well marked, and well known.—The influence exercised by respiration, in the animal economy, is pretty much the same in all animals; but the mode in which I have described it, principally applies to

man and quadrupeds, in whom the whole plan of the respiratory organs is exceedingly similar. In birds, there are some important modifications; in fish, as I have already mentioned, the air is applied to the blood in the gills, through the medium of the water; in amphibious animals, the principal characteristic is, that the whole of the blood does not circulate through the lungs, and that they can bear the interruption of respiration without injury; but in the insect tribe, and most of the inferior animals, there are various tubes, or tracheæ, which ramify over the body, and open externally by apertures, or stigmata, as they are called, by means of which the air is received and expelled: so that we witness, over the whole creation, an admirable accordance in the modes which nature has thought fit to adopt, for the support of life and health.—I shall now, however, mention to you the principal peculiarities of the function of respiration in birds, which are exceedingly curious. In this class of animals, the lungs are small, flattened, and lie close to the breast; but there is no diaphragm, and there is no alternate expansion and contraction of the lungs, as in the mammalia.

CHARLES.

But how, then, does the air find its way into the chest? For the action of the diaphragm, and the other muscles connected with respiration in the

mammalia tribe, by their expansion, produce a rush of air into the lungs, in order to avoid a vacuum being formed between the lungs and the chest; and by their contraction, force the air out.

DR. A.

In birds, the lungs have several openings, by means of which they communicate with various air-bags or cells, which fill the whole of the cavity of the body from the neck downwards. Now these cells are filled by means of air, which passes into, and out of them, through the lungs, and which, in its passage, produces those changes on the blood circulating through the lungs, which are necessary for the health of the animal.

CHARLES.

But this seems to be rather a complex sort of arrangement. Is there any reason why the same means should not have been adopted in them, as in the mammalia, for effecting the purposes of respiration?

DR. A.

You may recollect, that when I gave you an account of the bones, I mentioned that the bones of birds were hollow, for the purpose of admitting air into them through the lungs, and therefore for diminishing the specific gravity of the animal, and thus adapting it the better for being sustained in

so light a fluid as air. The same purpose is more effectually produced by means of the air-cells which I now mention to you. As these are hollow, and very expansible, shut up at one extremity, and only open to the lungs, it is clear that the animal, on acting with its muscles so as to elevate the breast and ribs, will produce a vacuum in these air-cells, which must be supplied by air which enters from the lungs. A continual and regular supply of air is therefore necessary to supply the wants of the system, as far as the lungs are concerned; but more or less is taken in, just as the animal has a wish to increase or diminish its specific gravity, in order to fit it, not only for walking on the earth, but soaring in the heavens, in all the varieties of density of atmosphere, which a greater or smaller proximity to the earth necessarily occasions.

HARRIET.

What a beautiful combination of office the lungs of birds thus possess; but it is quite clear, from what you have now mentioned, that no size or strength of wing could poise a terrestrial animal in air, unless there were the power of admitting air into the inmost recesses of his body, as happens in birds.

DR. A.

Certainly; and therefore wings are only to be regarded as one of the organs to which birds owe the faculty of flying; for an important part of

this office is owing to the diminished specific gravity, produced by the introduction of air in the way which I have mentioned.

HARRIET.

Then we may regard the body of birds as uniting a movable parachute, with a balloon; but in which the reception, or escape of gas, depend on the will of the animal.

DR. A.

The comparison is not altogether inappropriate; and I may observe, that so careful has nature been, in giving full effect to this structure, that the cells extend even among the muscles of the body, where they are particularly large in the soaring animals, as the eagle, hawk, stork, and lark.

SOPHIA.

I can readily now conceive, how the pouncing of birds from a great height is effected; for the animal has the power, at any instant, of forcibly compressing its whole body, and of thus giving itself a power of descent, which hardly any muscular effect could produce.

DR. A.

Certainly; and in diving birds the same power produces the faculty of sudden descent in the water, which is so necessary to them. The bar-

rels of the quills in birds, too, are hollow, and contain air; and it is said, that it is in some measure owing to the power of diminishing or increasing the contained quantity, that the turkey, bullfinch, &c. are able to produce the quick and voluntary erection of their plumage.—In fish, I have already stated, that the air is applied to the gills through the medium of the water. The gills are covered with a large flap, or operculum, which is made up of arched bones, covered with membrane, and edged with a fringe which can be accurately applied to the part beneath, so as to shut up entirely the slit, or opening into the gills. When the animal breathes, that is, when it wishes water to be applied to the gills, it acts with the muscles of this flap so as to render it convex; this cannot be done, it is clear, without producing a vacuum under the flap; and as the animal is in water, and there is an opening in the mouth which communicates with the gills, the water rushes in among the gills, filling up the space made by the changed form of the flap, and thus applying itself to the minute ramifications of blood-vessels diffused over the gills. When the air contained in this water is no longer equal to its purpose, the water passes away through the air-opening at the edge of the operculum, which the animal has the power of making; and by a repetition of the process, a fresh supply of water is obtained, and the function of respiration kept up.

CHARLES.

Then I suppose boiled, or distilled water, would not answer the purpose of supporting fish.

DR. A.

Unquestionably not; the animal would soon exhibit symptoms of uneasiness, unless the water contained air; and when a small pond is frozen over, the fish would die, by exclusion of air, unless an opening were made to admit a supply of this necessary article. There is, in fish, a part of structure somewhat analogous to the air-cells which I have just mentioned in birds, namely, the *air-bladders* or *swimming-bladders*, which are given to them, as to birds, for the purpose of increasing, or diminishing their buoyancy. These bladders are placed close to the back-bone; they vary in size, shape, and number; and are wanting, or are very small, in such fish as are generally confined to the lowest depths. They form what is called the sound of fish; a part which gourmands prize highly. When the air-bladder is ruptured, the animal loses the power of raising itself, and lies on its back, from the additional weight given to that part of the body, by the removal of the air.

SOPHIA.

But, as fish do not respire in the way of birds, in what manner does the air get into these bladders?

DR. A.

There is a power of forming, or secreting air, which is possessed by the vessels circulating in the membrane which composes them, and which is analogous to what is, in some cases, possessed by other organs, as the stomach.

SOPHIA.

But secretion must be a much slower process of filling the bladder than that employed in birds, when it can be admitted or thrown out at pleasure.

DR. A.

Unquestionably; but the air-bladder is ordinarily full, and is then capable of being acted upon, and compressed, either by the abdominal muscles, or by a muscular structure peculiar to this organ; and thus the air condensed, pursuant to the will of the animal, and an alteration made in the specific gravity accordingly. In some fish there is a communication between this bladder and the stomach, or gullet of the animal, and occasionally an appearance of valvular structure, from which it has been inferred, that the air is capable of being forced out according to exigency. This, however, does not appear very likely; for not only would the process of restoration be necessary, which could hardly be rapid

enough for the demand; but an escape of air in this way has never been observed.

CHARLES.

Has any examination been made into the nature of this air?

DR. A.

Most fish have a peculiar depth of water, at which they usually remain; and it is a curious circumstance, but one which was satisfactorily made out by Biot, that the nature of the air contained in the air-cells, has been found to vary very much, according to the depth which fish generally inhabit. Those which live in shallow water, have azote, with only a very small proportion of oxygen. As the depth increases, so does the oxygen; and after the depth of 150 feet, the average proportion was as much as 70 per cent, while the mean result afforded by fish caught at less depth, was only 29 per cent. Pike, carp, roaches, and perch, which are fresh water, and therefore shallow-water fish, had only from 3 to 5 per cent of oxygen.

CHARLES.

This singular difference would appear to indicate the greater purity of the air contained in deep water, than in that near the surface.

DR. A.

The supposition is a natural one; but so far is this from being the case, that the difference of pu-

rity, it would appear, is rather in favour of the air near the surface.

SOPHIA.

In what way can you collect the air from the air-bladders, so as to make it the subject of experiment?

DR. A.

If the air-bladder be opened under an inverted receiver filled with water, the air will ascend into the receiver and displace the water, just as you have seen it do in the chemical experiments which I have shewn you; and then it becomes the subject of experiment; like any other gas.—There is a curious mode of respiration employed by frogs, toads, chameleons, and some others of the amphibious tribe, which is, that the animal, instead of breathing through its mouth, keeps its mouth shut, receives air through its nose, and by means of the muscles of the jaws forces it into the lungs, from which it is returned, through the nostrils; by the action of the muscles of the abdomen, there being no diaphragm. With this conformation, those animals would be suffocated if their mouths were kept open.

The formation of the VOICE, I have stated to be one of the functions which nature has combined with respiration; and it is very curious, that it is not more than fifty or sixty years since this was the only, or principal use attributed to that function, which, we have seen, possesses so much influence

in the animal economy. I have mentioned the larynx to you, as forming the commencement of the organs of respiration. The opening into this, from above, is called the *glottis*, which is narrow, and of an oblong shape; and there is a little moveable cartilage lying over this opening, as a sort of defence to it, which is known by the name of the *epiglottis*. Now it is by means of the air passing through the glottis, that the voice is formed; for as this admits of various degrees of contraction, it gives to the current of air passing through it from the lungs, as bellows, all the varieties of voice in different animals possessing this structure, and all the different modulations of sound in the same.

SOPHIA.

' But is the voice entirely formed in the larynx? I should have thought that the nose and mouth had much to do with it, in as far as we owe our speech to the tongue, and observe a great difference in the tone of the voice, when there is any defect in the mouth or nose, or even in a common cold.

DR. A.

The various cavities of the nose and mouth, give a sort of resonance to the voice, and contribute to its force and clearness; but this is after its formation; and with regard to speech, this takes place by giving different directions to the sound when formed; the opening of the glottis, or the *rima*

glottidis, the chink of the glottis, as it is called, is regulated by ligaments at its sides, which are directed, through the medium of minute muscular structure, by the will, so as to be more or less contracted, and to be made more or less tense, and therefore to be susceptible of vibrations of various frequency, by the passing of the air through the opening. How minute these alterations of tension must be, may readily be imagined, from the easy mode in which the voice produces its numerous and rapid variations of note; and the correct manner in which it effects the various modulations of sound, of which it is capable. This is the more extraordinary, when it is considered, that the curious structure now mentioned, is adapted to a small cleft, not quite an inch long, and not more than two lines broad, which exhibits, to the eye of the most practised dissector, no difference between the apparatus of the most refined voice, and that of the coarsest and least perfect one.

CHARLES.

Then we may consider speech as consisting of two parts; voice or sound, which is formed in the larynx; and the divisions or modifications of sound, which are formed in the mouth.

DR. A.

Certainly. The various modifications of sound depend on the former; speech on the direction

given to the current of air in the mouth, by means of the tongue and lips.

CHARLES.

But I think we possess a power of speaking while we inspire, as well as expire. In this case, there cannot be a formation of the voice, previous to the formation of letters and words.

DR. A.

We can certainly exercise a sort of speech during inspiration, but that is only an inversion of the usual order of proceeding. The same action of the muscles of the glottis will produce sound, whether by means of air taken in or thrown out; and if the air goes to the glottis in a particular direction produced by the lips and tongue, as in the case which you mention, speech will be exercised, though much less perfectly and harmoniously, and much less under the management of the will than in ordinary circumstances.

CHARLES.

I can easily conceive that this must be the case; but in the curious art of ventriloquism, it would appear, that there must be some faculty appended to the ordinary one by which language is formed; for exhibitors in this way, do not seem to use their lips or tongue, or appear to a bystander to

be saying any thing, at the time that they are actively conversing in a feigned tone.

DR. A.

The mode in which ventriloquists perform their feats, is but little known. Some have thought that they really had an accessory organ of speech, or a sort of double or triple larynx, for which, however, there is no sort of evidence; and others, that their operations were to be accounted for by the voice being directed to certain echoing parts of a room, from whence it seemed to originate. But besides that, as you observe, they do not seem to us to employ the ordinary organs of speech, they are capable of exhibiting their powers, in any apartment which may be selected for them. It has been suggested, and with much appearance of probability, that ventriloquism depends on a certain power possessed over the glottis and its membranes, connected, perhaps, with more than ordinary nicety of construction, by means of which power, not only the voice, but words can be formed in them. It certainly seems to be by that organ, that parrots, jackdaws, and some other birds, even linnets and nightingales, imitate human speech; and there is, therefore, a great presumption of the same agency, as far as ventriloquists are concerned.

HARRIET.

There must, however, be a species of finesse

employed by the ventriloquist, in order to give an apparently different direction to his words, from what they really have.

DR. A.

Difference of force will imply difference of distance; and various little circumstances can be readily employed, so as to assist the illusion of the hearer, by withdrawing his attention from the person of the ventriloquist, and making the difference of tone and of force, more easily apply to difference of persons, and difference of distance.

HARRIET.

Is there any known instrument to which we can compare the voice?

DR. A.

It has been considered by some, as most analogous to a wind, and by others, to a stringed instrument; but the most perfect imitation, is that of the vox humana pipe in the organ, in which the sound is produced by the vibrations of an elastic plate agitated by a current of air, which it continually admits and excludes. In this formation the vox humana pipe resembles, very much, as far as we can judge, the mechanism employed in the larynx and glottis. Kratzenstein and Kempelen even made some pipes, which imitated very accurately many of the particular sounds of the human voice.

SOPHIA.

There must of course be considerable differences in the form of the larynx and glottis in different animals, from the organ which produces the roaring of the bull or lion, to that which gives us the sweet and diversified melody of the nightingale.

DR. A.

Very little is known concerning the precise mode in which the many varieties of sound are produced; but the examination of the organ of voice in different tribes of animals, exhibits certain variations of appearance, to which we may, without being able precisely to account for them, fairly refer some of the different phenomena of voice. The apparent differences are, however, mostly in magnitude, and cannot, it is obvious, inform us, why some animals neigh or bray, as the horse and ass; why the dog barks; the bull roars; the cat mews or purs; the sheep bleats; or the frog croaks.

The mammalia resemble each other in having the larynx and glottis at the upper part of the windpipe. In birds, there may be said to be two larynxes; one near the mouth, the other just before the division of the windpipe into the branches which enter the lungs. This latter is the glottis, the proper organ of voice; and it is possessed of a great variety of minute muscular structure, so as to admit of every degree of tension and vibra-

tion. The function of the superior larynx seems to be limited to the shutting up, more or less completely, of the upper opening into the trachea, by which means it assists the operations of the lower one. The power which birds have, as I have already noticed, of admitting a large quantity of air into their bodies, affords to them the means of keeping up a much stronger, and more continued current of air through the larynx, than any other animals can do; and gives them, therefore, a volume of voice, which is immensely great, compared with their small dimensions.

SOPHIA.

Is there any reason for supposing any sort of natural language among brutes, for the purpose of their communicating with each other?

DR. A.

I think it exceedingly likely that they have the power of expressing any strong feeling, in a manner which may be sufficiently intelligible to each other; for man can understand some of those natural expressions. But there is an immeasurable distance between such natural and instinctive indications of their wants, and the faculty of speech which man possesses, and to which he owes that most important and dignified enjoyment of life, the power of ready communication between mind and mind.

CONVERSATION XIX.

OF ANIMAL HEAT.

DR. A.

I HAVE already mentioned to you, that there exists, in the animal kingdom, a difference between some of the classes, from the possession of warm or cold blood. This is connected, in a considerable degree, with the varieties which occur in the nature of their respiration; for where the circulation of the whole mass of blood is carried on through the lungs, as in man, most quadrupeds, and birds, the temperature is much higher than it is in the amphibia, fishes, and various other animals, where there are either not lungs, or where the circulation through the lungs is incomplete.

HARRIET.

Is the difference of temperature considerable, then, between the cold and the warm-blooded animals?

DR. A.

Very considerable; for while the cold-blooded

animals generally preserve a temperature of two or three degrees only, above that of the medium which they inhabit; the warm-blooded are not only at a degree of heat which is very seldom reached in the open air, even in the warmer latitudes, but have a power of preserving that heat, under any changes of external temperature which have been known to take place.

HARRIET.

But would the temperature of the cold-blooded animals vary, with every change of temperature in the medium which they inhabit?

DR. A.

Within certain degrees only. For instance, frogs when kept for some time at a temperature of 115° were found to have the heat of their bodies raised only to about 80°.

SOPHIA.

Is the blood of all warm-blooded animals of equal temperature?

DR. A.

The human body has a temperature of about 98°; most quadrupeds of about 100°; while birds are at as much as 107° or 108°; and pigeons are even said to be at 109°. But fish generally, which are cold-blooded, preserve their temperature but little above that of the water in which they are im-

mersed; while the whale tribe, on the other hand, being warm-blooded, preserve, even in the polar seas, where the temperature is always near the freezing point, a heat very little different from that of quadrupeds.

HARRIET.

It is a fortunate circumstance for animals, that, considering the great variety of temperature which occurs in the course of the year, they are able to suit themselves so well to it; but to man, who is so wandering a creature, and who, in his ardour for scientific enquiries, or commercial pursuits, visits every part of the globe, this faculty is of great importance.

DR. A.

Unquestionably; the most sultry heats of the torrid zone, or the greatest cold of the polar regions, may not only be his natural and usual temperature, but may be those which, though a native of a very different region, he may bear with impunity. The heat in South Carolina, at Senegal, and on the banks of the Oronoko, has been as high as 115° in the shade; while in Siberia, in Greenland, and other parts of the high northern latitudes, even Europeans have been able to sustain a cold under which mercury has frozen, which you may recollect does not occur till it is at 40° below zero, or 72° below the freezing point.

CHARLES.

Then it appears, that the human race is not only capable of inhabiting regions, in which the temperature may vary to the extent of 155° (namely 115° added to 40°) but the same individual may bear, with impunity, variations to this extent.

DR. A.

Our adventurous countrymen, under the command of Captain Parry, used frequently to go, in less than half a minute, that is, in the time merely necessary to open two doors, from a temperature of above 60° (which was readily and constantly kept up by means of stoves) to 40° below 0°, and without inconvenience, even though the mouth was not covered; and it was observed by them, that if the weather was calm, they experienced less of the feeling of cold from so great a change, than to one of 0°, if there was considerable wind.

CHARLES.

This we continually observe in this country. But do animals bear these changes of temperature as well as man?

DR. A.

Animals are much more dependent on external circumstances; and their clothing, in time, becomes changed by the difference of climate to which they may be exposed. But so great is the cold which is sometimes experienced in the polar re-

gions, that the white bear, though a native of the climate, finds it beyond his tolerance, and he therefore disappears under the snow, leaving the field to the white fox,* which is alone able to bear the severity of the weather.

CHARLES.

The power which man possesses of protecting himself by warm clothing, gives him an immense superiority over every other animal, and is, of course, one of the means by which he is able to bear such varieties of climates.

DR. A.

Certainly; for the effect of cold air on unprotected parts of the body, is very soon to deprive them of vitality; and if proper means are not immediately taken to restore it, (of which a very important one is friction by snow,) mortification might be the consequence.—There were some very curious experiments made, many years ago, by Dr. Fordyce and Sir Charles Blagden, and subsequently by Drs. Delaroche and Berger, as to the extent to which the human body is able to bear great artificial elevations of temperature. They got small rooms heated, partly by flues, and partly by throwing boiling water upon them, so as to raise the thermometer to 240°; and they were able to bear this temperature, with a slight clothing only, without material inconvenience, and could have even borne a higher degree of heat.

SOPHIA.

But this is a temperature considerably above the boiling point of water.

DR. A.

So it certainly is; and yet the body could bear it with impunity. The touch of watch-chains, or any thing metallic, could not be borne for an instant; but at the same time that substances exposed to this great heat, acquired an increase of temperature, more or less rapidly, according to their nature, the body itself felt quite cold to the touch, and had but little elevation above the usual temperature. There was also this curious circumstance attending the experiment, that when the air was set in motion by bellows, it increased much the feeling of heat.

CHARLES.

This was, I suppose, upon the same principle, though conversely, as the sensation of cold, which is in ordinary circumstances produced during a wind. In the latter case, the heated air surrounding the body is carried off as soon as accumulated; while, in the former, the air which is cooled by its contiguity to the body, is carried off, and gives place to a fresh supply of heated air.

DR. A.

Certainly: and in the same way the siroccos.

and other currents of air which are heated above the temperature of the human body, will appear to the human body as the air of a furnace. The sirocco, I may observe, is mentioned by Brydone, as sometimes indicating a temperature of 112°.

SOPHIA.

Were any animals exposed to this high temperature in the experiments mentioned by you?

DR. A.

A dog was kept half an hour in a basket, in a temperature of 236°; he soon began to pant, and hold out his tongue; but he was so little affected, during the whole time, as to show signs of pleasure when they approached him: he was quite lively when liberated, and did not seem at all the worse for the experiment.

SOPHIA.

But in what way can this extraordinary want of power of such elevated temperature in affecting the body, be accounted for? In some circumstances heat becomes latent, but one does not see how this can happen in the present case.

DR. A.

In the first experiments, it was supposed that no elevation of temperature takes place in man, or other animals, by exposure to heated air, in the way mentioned. This, however, was subsequently

found to be not perfectly accurate. An elevation of several degrees, sometimes takes place under such circumstances; but this is still trifling when compared to the temperature withstood.—It was found, that on the first exposure, there was a great sensation of burning, which was, however, speedily relieved by an abundant perspiration, which, by its cooling operation, carried off the heat which might otherwise have produced more sensible effects on the body. So that you are so far right as to a certain quantity of the heat, to which the body was exposed, becoming latent, and thus losing the power of exhibiting itself in the usual way. In the dog, the same effect was produced by transpiration from the lungs, which, in that genus answers the purpose of exhalation from the skin.

CHARLES.

But is it certain that the appearance of great perspiration might not be deceptious, while it was really a deposit on the cooler body, from the vapour with which the room was filled?

DR. A.

A part might arise from this cause; but the agency of the former was indicated, by the effects of confining animals to high temperatures in steam, when evaporation from the surface was prevented. In such cases, the animal suffered

more from the heat, and had its temperature much more raised than in ordinary circumstances. It is to be observed, however, that even a higher temperature than that to which Dr. Fordyce and Sir Charles Blagden were exposed, has been sustained without inconvenience; for Tillet and Duhamel communicated to the academy of sciences, some years previously, an account of some females in the employ of a baker at Rochefoucault, in Angoumois, who were in the habit of going into an oven, heated to the temperature of 278° (105° of R.) remaining there 14 or 15 minutes, and suffering no particular inconvenience, unless they touched the surface of the oven, which, like the metallic substances in the experiments which I mentioned to you, communicated a heat that could not be borne.

HARRIET.

Were any other effects observed in those elevated temperatures, than what you have noticed relative to the bodies of the experimenters, or animals introduced with them?

DR. A.

Eggs were readily cooked, and steaks fried; and the cooking process was hastened, by blowing the warm air on the steak by bellows. Water was not made to boil, unless covered with a little oil or wax, which seemed to prevent evaporation, and in

this way, by confining the heat, allowed a sufficient elevation of temperature to take place.

HARRIET.

But I suppose it was only in heated air, that this elevated temperature could be borne. Much less than this would be more than could be sustained, I presume, in heated vapour, water, or other dense fluid.

DR. A.

It is a very curious circumstance, that the great Boerhaave, from some very inaccurate experiments which were made at his desire, formed the conclusion, that animals would perish, if exposed to a temperature above that of their own bodies; and that dogs, when so exposed, emitted speedily a most noisome and offensive vapour. The fallacy of these ideas, however, I have already pointed out. But it was one of the first circumstances known about the power of the human body to bear great heat, that vapour-baths, in Russia, are very commonly sat in, at the temperature of from 122° to 133°, not only without inconvenience, but with great comfort. The heat is produced by pouring water over red-hot flints.—It has even been said, that the temperature of vapour-baths has been borne in Russia and Finland as high as 45°, 50°, and even 60° of Reaumur's thermometer, equal to 133°, 144° and 167° of Fahrenheit's. The ordinary

temperature, however, does not seem much to exceed 120°; but this is an elevation at which heated water can hardly be tolerated; and immersion for three minutes in the Barege water, at 113°, produced much inconvenience. Spirit of wine was insupportably hot to the touch in Fordyce's experiments.

SOPHIA.

Is the heat of the body quite the same, in all temperatures of air, climates, and seasons?

DR. A.

Not exactly; for Dr. Davy found an elevation of one or more degrees of Fahrenheit, in the inhabitants of Ceylon, above that of persons living in northern latitudes. Seasons have likewise a certain influence on temperature, though the subject has been but little attended to. Sparrows were, however, found by Dr. Edwards, to be in February at 105°, in April at 107°, and in July at 110°. The same gentleman also observed, that the power which is possessed by animals, of producing heat, varies with the season; a low artificial temperature reducing the heat of sparrows, much less in winter, than in summer.

CHARLES.

Is it not probable that there may be a greater degree of vigour in the system, in cold, than warm

weather, which may make the powers on which the production of heat depends, greater in the one case, than the other?

DR. A.

It would be difficult to refer the circumstance entirely to such a cause; but, at the same time, if you would wish to have a little analogical support for your hypothesis, I may mention to you, that young animals, whether birds or quadrupeds, are for some time very dependent on their parents, for keeping up their temperature; and it would appear, from some experiments and observations made on the subject, that the minimum power of producing heat exists at birth, and that it increases up to the time of adult age; so that full-grown, or adult animals, can resist, more effectually than others, the operation of great cold.—There is a particular division of animals which deserves attention, and which I have not yet mentioned. It forms a part of the warm-blooded, and in summer, resembles the others of its class, in appearance and temperature. When the heat of the weather, however, falls below 50°, the nature of these animals seems entirely to change, and they appear gradually to undergo a metamorphosis from warm-blooded, to cold-blooded. They retire into holes in the earth, or in trees, and bury themselves in nests made of hay and dried leaves, when they fall into a kind of

sleep, and continue totally inactive, until the warmth of the sun rouses them into action, and restores their pristine state of existence. They roll themselves up; become rigid; their respiration being slow, weak, irregular, and for a long time suspended; and their temperature very much diminished. Digestion ceases; they take no food; and the action of their muscular, absorbent, and nervous powers, is for a time suppressed. These animals are called *hybernating*.

HARRIET.

What an extraordinary change; and how remarkable must be the nature of the animals which are subject to such an alteration of appearance. But are there many animals which undergo this extraordinary change?

DR. A.

Not a great number, though there are some in all the classes, except fishes and birds. Among the mammalia, are bats, hedgehogs, dormice, and marmots; in the other classes, are flies, insects, worms, snakes, and oviparous quadrupeds, including under that title, frogs, toads, and lizards.

SOPHIA.

But then it is only in the colder climates, I suppose, that the phenomena of torpidity occur.

DR. A.

In no others; and hence, during the whole year, the insect and snake tribes preserve their noxious qualities in the warmer latitudes.

SOPHIA.

But how is it possible that animals can live without food, and with an almost total suspension of all the functions of life?

DR. A.

It is because the functions of life are suspended; by which means there is not the demand on the constitution, which occurs during active existence; and therefore not the continual waste which requires supply.

CHARLES.

Then I suppose the temperature falls nearly to the degree of the atmosphere?

DR. A.

Within a few degrees of that to which they are exposed; but you will recollect that hybernating animals conceal and bury themselves in situations, where the external air has not its full force. Their temperature, however, always remains some degrees above that of the atmosphere; and it therefore appears, that they have a power of generating

heat, though in a small degree compared to the non-hybernating animals.

HARRIET.

But would exposure to considerable cold during the summer have the same effect?

DR. A.

In many it has been tried; and exposure to freezing mixtures, or confinement in icehouses, have diminished temperature, and produced temporary torpidity.—There is a curious circumstance which attends the exposure of torpid animals to noxious gases, as the carbonic acid, azotic, or hydrogen gases. As they breathe very imperfectly, or not at all, when in this state, they suffer no injury when immersed in them; but as soon as they begin to revive, and to breathe, the destructive agency of these gases is felt. Torpidity, however, exists in various degrees; and hence respiration, and the change effected by it in atmospheric air, are much diversified. The power of taking food likewise varies, being totally interrupted when the torpidity is complete.

CHARLES.

Has the experiment to keep off torpidity by artificial warmth been tried?

DR. A.

In several instances, particularly among marmots, which, in warm rooms, and with a plentiful

supply of food, could be kept in activity during the whole of the winter.

CHARLES.

The effects of heat on the hybernating animals, seem to bear some kind of analogy to what we observe of plants. When the cold approaches, their leaves wither and droop; they soon lose their beauty, and in a considerable degree their external character, which is only restored by the return of spring and of warmth.

DR. A.

You are quite right: heat is indeed one of the most important agents which nature employs in the production of that continual series of changes which are every where exhibited, whether in the animate, or inanimate world; whether in the animal, vegetable, or mineral kingdom. Every body in nature possesses a certain quantity of it, which is, as you know, either in the sensible or latent state, or both; and the sun is the great means by which temperature is kept up, or renewed. The animal body is itself, however, a system in which heat is generated for its own peculiar wants; and in this we see a beautiful provision of nature for the independence of the animal, and for the proper carrying on of its functions, under almost every variety of temperature.

SOPHIA.

I am very anxious to know in what way this continual production of heat is effected. It is a wonderful process.

DR. A.

I shall endeavour to give you a general view of what is known on this subject; but it is one of great difficulty, and many points relative to it require further elucidation. After the modern doctrines on chemistry had thrown a light on the phenomena of combustion, which had not been received before, attempts were made to apply the same principles to account for the production of animal heat.

SOPHIA.

But was it not rather a wild speculation to suppose any analogy to exist between combustion, in which the heat is exceedingly elevated, and animal heat, which rises so short a way in the scale of temperature? unless, indeed, we are to imagine, that there is something of a furnace within us, from which the heat of our bodies is derived.

DR. A.

You hardly, however, recollect the phenomena of combustion, or you would not consider the analogy to be so imperfect.

SOPHIA.

Combustion, if I mistake not, is the rapid combination of a body with oxygen, by means of which heat and light are disengaged; but in the animal body there is no appearance of any thing of this kind.

DR. A.

That is, it is not perceptible to the senses, as in the case of combustion; but still, a very similar process is going on, though much more slowly. Combustion requires, you know, the contact of oxygen, or at least of atmospheric air, which contains it. If it is carried on in oxygen, in closed vessels, the oxygen either combines with the burnt body, and thus alters its nature; or a part of the burnt body unites with the oxygen, to form a new substance, called carbonic acid gas. Now I have mentioned to you, that in respiration, oxygen disappears, and carbonic acid gas is formed. So far the processes are similar; but as this goes on very slowly in the lungs, there are none of the usual phenomena of combustion produced, which take place during combustion out of the body.

CHARLES.

But I do not understand in what way heat is elicited in consequence of the production of carbonic acid gas, by the union of the carbon of the blood with the oxygen of the air, brought into

contact with the lungs. If the oxygen had become fixed, and its gaseous form had disappeared, I could easily conceive that the heat necessary for maintaining it in the state of air would be evolved, just as when vapour becomes water, or water ice; but it was gas before its contact with the lungs, and gas afterwards.

DR. A.

Your objection is a very fair one; and the circumstance depends on that particular principle in chemistry, which is termed *capacity for heat*. This is the particular quality or disposition which bodies possess, by means of which they require different quantities of heat to raise them to the same temperature.

HARRIET.

I recollect that in the Conversations on Chemistry, this principle is exemplified by the different heating of similar weights of three different bodies, lead, chalk, and milk, when placed in an oven. The lead heated first, the chalk next, and the milk most slowly, though they were all exposed to similar temperatures.

SOPHIA.

And it was further exemplified, that these bodies possessed different quantities of heat in them, by the different quantities of heat which they were

able to communicate to equal quantities of water*; the lead raising the temperature of the water least, the chalk more, and the milk most.

DR. A.

You are quite right in your recollections; and in the same way, the oxygen gas has a greater capacity for heat than carbonic acid, or requires a larger portion to bring it to the same thermometrical temperature; and therefore, in the conversion of the one into the other, heat is evolved. But if their capacities for heat were the same, it is certain that no evolution would take place during the change of the one into the other.

HARRIET.

Are the lungs, then, found to be hotter than other parts of the body? This must be the case, one would imagine, as heat is elicited in them.

DR. A.

You have hit upon one of the most staggering objections to the theory, that which, in the mind of the proposer of it, Dr. Black, seemed to be an insurmountable difficulty; for, in point of fact, there was found to be no greater temperature in the lungs, than in other parts of the body; but here the doctrine of capacity for heat, in reference to the blood, was had recourse to, to remove the difficulty. I have already mentioned to you, that

the blood is changed from a dark, to a florid red, in the lungs, in consequence of the influence exercised upon it by atmospheric air. It was considered that the capacity of the florid, is greater than that of the dark-coloured blood; and that when the latter became converted into the former, the heat which was elicited from the atmosphere, and would have raised the temperature of the blood in the lungs, was, as it were, absorbed, and its sensible effects suspended.

CHARLES.

So that, in point of fact, though both descriptions of blood would be of the same apparent temperature, yet they would actually possess different quantities of heat.

DR. A.

Certainly.

CHARLES.

But then in what way would heat, according to this idea, be extricated over the body?

DR. A.

By means of the conversion of the florid into the dark-coloured blood; for as this takes place all over the body, wherever arteries terminate in veins, heat would of course be elicited, and in a very gradual and uniform way, merely by the conversion of the arterial into venous blood. This

was a very beautiful and satisfactory view of the subject; and as the difference of the capacity for heat, of arterial and venous blood, was supposed to be as 114.5 to 100, there was difference enough to account for the effect produced; but, unluckily for this theory, it has since been discovered by Dr. Davy, that the difference of capacity, between the one and the other, is so small, as not to be sufficient to account for the phenomenon in question.

HARRIET.

How very perverse it is, that when a theory has been discovered, which accounts satisfactorily for every difficulty in a subject, we should all at once have our views unsettled, and be turned adrift into the world of doubt and uncertainty.

DR. A.

It is doubtless a hard case, though not an unfrequent one; but these are disappointments which must be borne with fortitude by all who have truth for their object.—There is another objection, however, which is not less unmerciful on the chemical theory of animal heat, than that which I have now mentioned: it is this, — that after an animal has been decapitated, the circulation of the blood through the heart and lungs can be kept up, and the change of its colour from venous to arterial, produced, without any production of animal heat.

This, therefore, evinces that there are many obscurities in the subject, which have not been yet removed.

HARRIET.

But in such cases, were the changes produced on the air respired, just as in ordinary respiration?

DR. A.

They were very similar; carbonic gas was formed, and oxygen disappeared.

HARRIET.

Then it would appear, from this extraordinary and repulsive experiment, that respiration is in no way connected with the production of animal heat, since the air exerts its proper influence on the blood, and no heat is produced.

DR. A.

And yet we cannot at once reach this conclusion; for the animals which have the most perfect system of respiratory organs, have most heat; and in them it is uniformly observed, that whatever quickens the circulation through the lungs, will augment temperature; and whatever retards the circulation, will diminish it. This, therefore, evinces a connection between those functions, which is not yet thoroughly understood. I may observe, however, that some later experiments, made both in

France and in this country, show that Mr. Brodie's experiments (for it is to that able physiologist that we are indebted for them) are not so irreconcilable, as was originally imagined, to the chemical theory of respiration. It is to be remarked likewise, that when carbonic acid is formed out of the body, by the combustion of carbon in oxygen, (which is a process similar to what occurs in the lungs.) there is found to be an elicitment of a very large quantity of heat, which, it is reasonable to suppose, would be disposed of in heating the body, where the same phenomenon goes on within it.

CONVERSATION XX.

GROWTH AND DECAY.

DR. A.

In the general views which I have endeavoured to communicate to you, relative to the animal economy, I have treated of those functions, which tend to the support of life and strength, and which are connected with the exercise of the particular powers and properties, for which the animal is destined. We have got nearly to the termination of the plan, which I meant to pursue for your amusement and instruction, in our late meetings; and it is my intention, on the present occasion, to give you some information relative to the growth and decay of the body, as a finále to our operations respecting the animal economy for the present.

The whole of the organs of the animal body are intended as a mutual support and protection to each other. Nourishment goes on at all periods of life, but in very different degrees. In infancy and youth, it is intended that the various parts of

the body should expand to their designed size; and the food which is taken in, is therefore not only destined to support, but to enlarge. Growth, however, is limited by that law which nature has attached to every object in the creation; and after maturity has been obtained, the principle of decay, which is inherent in our natures, soon becomes manifest. The apparatus which is attached to life, is to last but for a certain time, in spite of the admirable provisions which exist for preserving health, and for warding off disease.— At the earliest periods of existence, growth is exceedingly rapid, and nature seems to be solely occupied in contributing to it. The alternations of food and rest, occupy nearly the whole time; and it is not till a certain portion of size and strength are obtained, that other objects can be attended to. This is, however, principally the case with man; for in many parts of the animal creation, the young soon obtain a certain independence of their parents.

HARRIET.

The recruit which is obtained by sleep, appears to be a very wonderful provision of nature, for restoring the energy of the frame.

DR. A.

A very extraordinary and admirable one, in which, during an oblivion of every external cir-

cumstance, the body obtains a revival of its powers, and the capacity of resuming its exertions. Mere quiescence is not sufficient to restore the animal strength after fatigue. That can go only a certain way; but in the effects of the balmy influence which sleep exercises, the mental and bodily faculties obtain a sure, and constant renewal of their energies.

CHARLES.

We are, I presume, to take sleep as a fact, which is not to be accounted for, any more than the operations of mind, or the connection which the mental and bodily part of our frames have together.

DR. A.

Some endeavours have been made, on mechanical principles, to account for this phenomenon, but they have been quite insufficient; and we must be satisfied on this, as well as various other subjects of an obscure nature in physiology, to attend to facts, and not to burthen ourselves with useless, and unavailing hypotheses.—The soundest sleep is enjoyed during complete recumbence, when there is a total cessation of all voluntary exertion. Sleep is, however, occasionally to be obtained, in great fatigue, under almost any circumstances. It has been said, that during the battle of the Nile, some of the boys were so overpowered with

fatigue, that they lay down and slept most heavily, amid the hottest of the action. Couriers and postillions have often been known to sleep when on horseback; and it has been stated that many of the soldiers of General Moore's army fell asleep during their march, and continued walking on, notwithstanding this occurrence.

SOPHIA.

It seems to be hardly credible, that persons should be able to sleep without falling.

DR. A.

And yet we know that there is such a thing as somnambulism, or walking in sleep; which, though not quite a case in point, shows clearly, that under particular circumstances, a certain command may be retained over the limbs during sleep. Perhaps the greatest privation to which the body can be subject, is want of rest; and the utmost refinement of punishment which can be inflicted, is that of continually interrupting and preventing sleep, as we read has been done by some tyrants of old. Captain Barclay's exertion of walking 1000 miles in 1000 hours, was a very great one, merely viewed as being 24 miles a day, for above 40 days. It was, I imagine, more than any horse could go through; but when you consider that it was two miles every two hours, so as that never

more than one hour and a half's sleep at a time could be obtained, it is quite extraordinary how he could accomplish such an enterprise.

SOPHIA.

I am afraid it is a tender subject to touch upon with us; but I should like to know what quantity of sleep may be considered to be necessary in the 24 hours?

DR. A.

Much depends on habit, and something on original constitution: but few people can do without six or seven hours' sleep, and none ought to have more than eight or nine. Laborious students, however, and others who are very provident of their time, have limited their sleep to four or five hours, or even less.—During sleep, there is a gradual diminution of animal action. The pulse becomes slower; the process of digestion goes on less vigorously; and there is a slight approach to that sort of suspension of action, which occurs in the hybernating animals. The diminution of heat which occurs during sleep, is well marked by the circumstance, that if persons fall asleep with only their usual clothing, they often find themselves exceedingly chilly on awaking.

SOPHIA.

When people dream, is it from their sleeping less sound, and from the powers of the mind being

therefore less completely suspended, than in ordinary circumstances?

DR. A.

This is not unlikely; because we generally find, that a first sleep is more sound, and is freer from dreams, than a second, or what occurs nearer the time of rising.

HARRIET.

What a very extraordinary thing dreaming seems to be. It appears as if some of our faculties were as acute, or even acuter, than ordinary, while others are totally suspended.

DR. A.

We certainly feel ourselves able to perform, with perfect facility, all the ordinary actions of life, but have a most extraordinary want of recollection of past events; so that we can act with persons who have been long dead, and with a total oblivion of events and circumstances long gone by. It is likewise curious, that, though we may seem to possess our usual judgment, and power of observation, in many things, our dreams often exhibit a great wildness and inconsistency, which pass by without offending us, or appearing to be at all extraordinary.

CHARLES.

We seem to go on, from subject to subject, in a

very desultory way, and as though we had no command of our thoughts; and I suppose that various circumstances which have recently taken place in waking hours, may make our ideas take a particular direction.

DR. A.

This is unquestionably the case; and it seems as if, when once a particular direction was given to our ideas, our imagination went on in a most uncontrolled way, and seemed to be on the watch for new trains of association, and for new and often grotesque and fanciful combinations. The effects of various diseases, particularly indigestion, and some of those which affect the chest, in producing unpleasant dreams, are well known; and every one has occasionally felt, that a late and heavy meal, will give rise to various unpleasant dreams, and go to the extent of producing nightmare. I heard the late Professor Gregory, when I attended his lectures many years ago in Edinburgh, give a curious example of the effect of a bodily impression in producing a dream. He was at Rome, and being ill of fever, sinapisms, or mustard poultices, were applied to his feet: these, when they began to take effect, produced a considerable heat in those parts, and made him dream that he was ascending Mount Ætna, and that he found the heat of the ground insupportably great.—It is

the readiness with which dreams follow certain trains of association, and the want of any apparent control over them, that led Mr. Dugald Stewart, in investigating the state of mind during sleep, and in considering what faculties continue, and what are suspended at that time, to form the opinion, that during sleep, those operations of the mind are suspended, which depend upon the will; the succession of thoughts following the usual laws of association, without having that sort of influence exercised upon them, of which we are capable, when awake.

CHARLES.

So that memory and judgment, Mr. Stewart supposes, are suspended, because their exercise requires a certain voluntary exertion on our part; and, hence, we neither compare the circumstances which seem to be passing before our eyes, with past events, nor discover their extravagance or inconsistency.

DR. A.

Such is his opinion; and a part of his theory depends on the supposition, that trains of ideas are continually passing through the mind, both in sleeping and waking; or, in other words, that we always dream during sleep, but do not always recollect our dreams.—In the period of infancy, a larger portion of sleep is necessary than in after life.

The same is the case in old age, when nature is soon exhausted, and seems, with the occasional loss of faculties, to go back to the feebleness of early life.

CHARLES.

There must, I should imagine, be great original differences in the strength of individuals, as indicated by the various periods at which old age exhibits itself.

DR. A.

I have no doubt that there are such differences, independently of the effects produced by various habits of life. It is very seldom, however, that old age is allowed to make its quiet and imperceptible inroads. The numerous accidents to which we are subject, and the various causes of disease which are continually in operation, leave but few to die of old age. The earlier that the human species advances to maturity, the sooner is the approach of age; and, in some curious examples, where maturity occurred during infancy, the decline of life came on at little more than the usual adult period. In southern climates, likewise, where maturity is early, age comes on rapidly.

HARRIET.

Is there any reason for supposing, that there is much difference between the modern period of life, and that of ancient times?

DR. A.

David speaks of the age of man being, in his time, only threescore years and ten, or in very rare cases, fourscore years, which is what we may regard as the general limit of human existence at present; nor does it appear that the ancients, at all exceeded the average length of life in modern times. Of course, we set aside that extraordinary duration of existence, which is described in the early part of the Mosaic history, and was destined to afford a better opportunity for peopling the earth.

CHARLES.

I think the famous Parr lived to the age of 152 years, and Jenkins to 169. It would be curious to know whether their families were at all distinguished for longevity.

DR. A.

It has been said that Parr's was; and it is not unlikely that the stamina, which persons who live to advanced periods, possess, may be capable of transmission. Parr's grandson, Michael Michaelstone, lived to the age of 127, and died in the year 1763.—There was a curious statement made out some years since, relative to the ages of the resident pensioners of Greenwich Hospital, amounting at the time to 2410 in number, from which I shall point out the principal particulars. Of this num-

ber, 96 had attained to, or passed the age of 80; one only was above 100; 15 were 90 or more; and 80, were 80 or more. About 42 of the 96 were of aged families; and in some of this number, both parents had been aged. 80 of the 96 had been married: 79 were in the habit of using tobacco in some form or other; and 48 had drunk freely. 20 were entirely without teeth; 52 had bad, and 14 good teeth. But the oldest man in the house, who was 102, had four new front teeth within the five preceding years. Vision was impaired in about one half; and hearing, only in about a fifth part of the number.

SOPHIA.

How pleasantly Greenwich pensioners must live, amid a total freedom from care, and with nothing to do but to enjoy themselves among many of their old cronies; fighting over again their battles, and snugly comparing their adventures, and talking about their hair-breadth escapes.

DR. A.

Yet it is not amid the greatest apparent aptitude for enjoyment, that the human mind usually possesses most pleasure; and I fear that their total want of care, the monotony of their lives, and the absence of regular employment, may sometimes make their time hang a little heavy upon their hands.' Greenwich Hospital is,

however, a noble asylum, worthy of a great nation to support; and nothing is a more agreeable sight, than that of a veteran, who, after having served his country with honour, gratefully reposes on its bounty; and, with such an interest in passing events, as binds him reasonably to this world, makes a prime object in preparing for the next.

HARRIET.

Does longevity, as far as you know, occur most in the higher, or the lower orders of society?

DR. A.

I should say most in the lower; for the higher, and even middle classes, are subject to various causes of indisposition, which do not attach to those who are much below them. Old Parr, and Jenkins, both of them lived, from necessity, on the coarsest fare. The former married when at the age of 120: and when at 130, was able to thrash, and to do any description of farmer's work. He was brought from the pure air, and homely diet of the country, into the family of the Earl of Arundel, in London, where he drank wine and lived luxuriously; and he was, in consequence of such a change in his mode of living, speedily carried off.

Many of the instances of longevity have occurred in workhouses, where, though there is generally a sufficiency of the plainest food, there are

no luxuries; and the plain diet, and invigorating employments of a country life, are certainly more favourable to health, than the close air, and refinements of towns; though it is not to be forgotten, that the country labourer, who is exposed to all weathers, is exceedingly liable to the complaints which arise from cold and damp.

CHARLES.

It must likewise be borne in mind, in any calculation of the proportional mortality of the higher and lower orders, that as the latter are so much more numerous than the former, one case of longevity, in the higher orders of society, counterbalances several in the lower.

DR. A.

This must certainly be the case; and it is a circumstance which does not seem to have been sufficiently attended to. — It has been said that there have been greater examples of longevity in Great Britain, than any other country of Europe; and a curious circumstance is mentioned by Sir William Temple, on the authority of Philip de Comines, that none of the kings of France lived to threescore, from the time of Charlemagne to that of Louis the Eleventh; whereas, in England, from the Conquest, to the end of Queen Elizabeth's reign, (which is a much shorter period) there

have reigned five kings, and one queen, whereof two lived 65 years, two 68, and two reached at least the 70th year of their age. Sir William Temple likewise states, that he was informed by M. Pompone, the French ambassador at the Hague, where Sir William was ambassador from England, that he had never heard of any man in France who had arrived at 100 years. — It is very clear, however, that, notwithstanding the variation which there may be in the longevity of the human race, in different countries or districts; and in spite of the continual complaints which are made of the shortness of life, man is a long-lived animal. He is exceeded, in length of years, by but a very few of the other inhabitants of the globe.

SOPHIA.

Very long life is hardly desirable, since it must leave a person very much alone in the world; and diminish the value of existence, by the want of sympathy with those around us, on which so much of the comfort of life depends.

DR. A.

And yet life always possesses certain attractions; and few have such a position of feeling, as to be willing to give up animal existence, without a struggle for its preservation. The human mind gradually reconciles itself to new circumstances;

and frequently possesses, even in the most desolate, and adverse state of things, certain sources of enjoyment, into which it is difficult to enter.

HARRIET.

But the wreck of mind is the most humiliating to our nature; and I hardly know any thing more painful than the second childhood to which some are reduced.

DR. A.

It is a serious lesson on the evanescent nature of sublunary things, that not only our corporeal strength, but the proud exercise of those faculties, which place man so much above every other animal in the creation, are of very short duration. The most powerful monarch, the most distinguished philosopher, poet, and statesman, are equally destined, in a few years, to sink into dust; and, before the close of life, frequently to exhibit, with the loss of their bodily vigour, a diminution, or disappearance of those powers of intellect, which governed, instructed, or delighted mankind.

HARRIET.

Is there any reason for supposing that the ancients exceeded the moderns in height?

DR. A.

The magnitude of ordinary men does not appear to have been greater, at those periods, when so

much depended on personal prowess, than in modern times, when, by the changes introduced into the mode of warfare, the powers of different individuals are so much equalised. There are differences, within certain bounds, in the size both of nations and individuals; and instances sometimes occur of monstrosities, both in largeness, and smallness of dimension. Giants have been mentioned, of from seven feet to nine feet in height, and sometimes much more: though this last seems to be the utmost limit of stature for which there is tolerable evidence. Dwarfs, on the other hand, have occurred, of from 40 inches, to about 16 inches in height. But in all these deviations from usual size, there is generally something irregular and anomalous in structure and appearance; and Nature seems to have reserved her greatest beauty, symmetry, and activity, within certain moderate limits.

CHARLES.

The bulk of man depends, I suppose, in some degree, upon his mode of living; but I have often been surprised at the difference which occurs between men and brutes, as to the power of augmenting their size. A farmer may pretty securely depend on fattening an ox or a sheep on a good pasture; but some people are lean and lank under plentiful diet; and others seem to get large on a moderate, or even a small quantity of food.

DR. A.

The more removed mankind are from a state of nature, the more dependent they seem to be on accidental circumstances. In the savage state, probably, a man might be as certainly fattened as an ox; and we learn that during the sugar season in the West Indies, the negroes always become plump. Even with us, butchers and innkeepers are very often large; for they live well, and have just enough exercise to preserve them in health. But a soldier, a sailor, and a postillion, though they have plenty of good food, are prevented by their respective professions from carrying much flesh. There have been many examples of persons who have become very large, gross, and diseased, by indulgence; and who, by a material alteration in their mode of life, have reduced themselves to moderate dimensions, and have recovered their health; and one has occasionally heard of some calculating gourmands, who, after certain periods of enjoyment in all the luxuries of the table, have starved themselves for a time, in order to resume their sensuality with less risk.—A curious example of the good effects of temperance, in recovering and preserving health, occurred in the famous Lewis Cornaro, a noble Venetian, who was originally of a feeble constitution, and by irregular indulgences, brought himself, at the age of 40, to the brink of the grave. He adopted a rigid

course of temperance and sobriety, on being told that this was the only chance he had for his life; and he lived to above 100, going off like one in a sleep. He allowed himself not more than 12 ounces of food, and 14 ounces of drink, in the day; and when he was above the age of 70, the experiment of adding two ounces to each, by the advice of his friends, had nearly proved fatal to him. The food that he employed was nutritive, and his drink small wine.—But one of the most extraordinary instances recorded, of the restoration of health, and reduction of size, by temperance, was in Thomas Wood, the miller, of Billêricay, in Essex, who, under full living, became very corpulent about the age of 40; and at 44, had many threatenings of apoplexy, and other serious maladies. On reading the life of Cornaro, he altered his mode of living, so as gradually, but in no long time, to reduce himself 10 or 11 stone. He entirely recovered his health and strength; and died of an inflammation of his bowels, brought on by cold, at the age of 64. The daily nutriment which he found perfectly adequate to his comfortable support, consisted of a pound of the flour of which the best kind of sea biscuit is made, boiled into a pudding, with a pint and a half of skimmed milk. He used a great deal of exercise, and took about five hours' sleep. At one time, when he took three pints of skimmed milk,

and two eggs, with his pudding, he thought he got fat, and therefore made a reduction to what I now mention, which became his usual daily nutriment. I have talked with Mr. Wood's son, who occupies the house in which his father resided, on the subject of his father's singular history; and have seen two or three manuscript volumes of correspondence, mentioned by Sir George Baker in the account which he published of the case, and to which the success of this curious discipline gave rise. One of Mr. Wood's imitators, it is said, having, from faith in the efficacy of the pudding, had it made with every regard to punctilious accuracy, long persevered sedulously in its use. You will not, however, be surprised at the difference of effect, when I tell you, that he took it in addition to, and not in the place of, his ordinary luxurious repast.

CHARLES.

We have an example, in the reduction of weight in jockeys, of the effect of spare diet and exercise on the human frame. Are you acquainted with the mode pursued by them in accomplishing their object?

DR. A.

In general, when feats of strength and activity are to be performed, either by men or animals, a certain *training* is employed, by which they are

brought to the best possible state of health and strength, both in wind and limb. This was done with the ancient athletæ, and is practised likewise now-a-days, in fitting men for boxing, or for running matches; horses for racing, and cocks for fighting. But the jockey has a totally reverse plan pursued with him; and being obliged sometimes to reduce himself to a very low weight, in a very short time, he can only do so by starvation, exercise, and profuse sweating. It is said, that he can effect the object of a reduction of a stone and half, or even more, in as short a time as a week or ten days. He eats very sparingly; takes wine and water for his drink; walks daily 15 or 16 miles, with five or six waistcoats or more on him, two coats, and as many pairs of breeches, by which means he is made to perspire very profusely; and takes a good deal of rest. In the instance of John Arnall, when rider to his present majesty, then prince of Wales, who was desired to reduce himself as much as possible, in order to ride some favourite horse, no animal, or even farinaceous food, was taken for eight succeeding days; but only a piece of apple occasionally. He was not injured by this discipline; and it appears, that when jockeys resume their ordinary mode of living, they very speedily recover their flesh, though they are seldom, at any time, more than nine stone in weight. You thus see what a singular power the animal frame possesses, of

accommodating itself to a great variety of circumstances. This is wisely and bountifully intended, without doubt, to increase the sphere of our gratifications and usefulness; though it is often perverted to mean and ignoble purposes.

But after all the exertions of the best regulated, and the most useful life: after nature has availed herself of her numerous resources to preserve health, and to keep off disease; after all those curious compensations and adaptations which the study of our frame lays open, have been called into repeated operation; there is, most surely and inevitably, whether at the usual period of old age, or at that more extended limit of existence, which a very few only are destined to attain, a failure of the powers connected with life. The bodily organs are unable to carry on their functions; they become inanimate matter; are decomposed into their original elements; revive again in new shapes, in plants and animals; and in this way, assist in the continuance of those series of existences, which were commenced by the fiat of the Deity, and are continued by the laws to which he has given origin.

The principle of life is wholly unknown to us. We cannot detect, by the nicest powers of human discrimination, the circumstances on which depend the difference between a living body, in the fulness of health and beauty, where an ample and interesting series of active operations is uninter-

ruptedly, and to all appearance spontaneously, going on; and the same body, a mass of lifeless matter, subject alone to the laws which inanimate substances are made to obey. But if the nature of vitality, of that principle which is common to the whole animal, and in some measure to the vegetable kingdom, is concealed from us by an impenetrable veil, still more is that of the sublime and immortal part of our constitution, which approximates man to the Author of his existence, and fits him for contemplating the wisdom, the beauty, and the harmony of those operations, which are continually going on around him.

CUVIER'S DIVISION

OF

THE ANIMAL KINGDOM.*

DIVISION I. VERTEBRATED ANIMALS, or those having a vertebral column or back bone.
DIVISION II. MOLLUSCA, animals of soft texture.
DIVISION III. ARTICULATED, or jointed animals.
DIVISION IV. ZOOPHYTES, animal plants, or radiated animals.

DIVISION I. VERTEBRATED ANIMALS. Four Classes.

CLASS I. MAMMALIA, animals which give suck.

ORDER I. BIMANA, or two-handed; man only.
ORDER II. QUADRUMANA, or four-handed; monkeys of all kinds.
ORDER III. CARNASSIERS, or flesh-eating.

SUBDIVISION I. CHEIROPTERA; winged-hands; as the bat.
SUBDIVISION II. INSECTIVORA; living on insects; as the hedge-hog, shrew-mouse, and mole.

* Referred to in vol. i. p. 47.

SUBDIVISION III. CARNIVORA; carnivorous.

A. *Plantigrade;* which walk on the soles of the feet; as the bear, racoon, badger, and glutton.

B. *Digitigrade;* which walk on the toes; as

(a) Weasels.
(b) The dog kind; domestic-dog, wolf, fox.
(c) Civet-cat.
(d) Hyena.
(e) The cat-kind; lion, tiger, leopard, panther, lynx, common-cat.

C. *Some of the amphibious;* as seals and walruses.

D. *Marsupial* or *pouched animals;* as kangaroos and opossums.

ORDER IV. RONGEURS, rodentia, or gnawers; as castors, beavers, rats, mice, marmots, squirrels, porcupines, hares, rabbits, guinea-pigs.

ORDER V. EDENTÉS, edentata, or toothless; as the sloth, armadillo, pangolin, ornithorynchus.

ORDER VI. PACHYDERMATA, or thick-skinned; as the elephant, hippopotamus, pig, rhinoceros, horse, ass, zebra, quagga.

ORDER VII. RUMINANT; as the deer, antelope, goat, sheep, cow, buffalo.

ORDER VIII. CETACEA, the whale-tribe.

CLASS II. BIRDS.

ORDER I. BIRDS OF PREY.

SUBDIVISION I. DIURNAL; as the vulture, falcon, eagle, hawk.

Subdivision II. Nocturnal; as the owl.

Order ii. Passereaux, or the sparrow tribe; as the magpie, swallow, thrush, sparrow, crow, wren.

Order iii. Grimpeurs, or climbers; as the woodpecker, cuckoo, toucan, parrot.

Order iv. Gallinacés; the gallinaceous or poultry-tribe; as the peacock, turkey, pheasant, barn-door fowl, partridge, pigeon.

Order v. Echassiers, the stilted or waders; as the ostrich, cassowary, plover, crane, heron, stork.

Order vi. Palmipèdes, or web-footed; as the pelican, duck, swan, and goose.

Class III. Reptiles.

Order i. Chéloniens, or tortoises.

Order ii. Sauriens, the lizard tribe; as the crocodile lizard, gecko, and chamelion.

Order iii. Ophidiens, the serpent tribe; including the boa constrictor, and such serpents as are not venomous, as well as the venomous serpents.

Order iv. Batriciens, the frog tribe; including frogs, toads, salamanders, the proteus, and syren.

Class IV. Fishes.

Series i. Chondroptérygiens, or the cartilaginous; as the lamprey, shark, skate, thornback, sturgeon.

Series ii. Osseux, the bony, whose divisions are principally taken from the gills, jaws, or fins; and are

ORDER I. *THE PLECTOGNATHES*; as the sun-fish, trunk-fish.

ORDER II. *THE LOPHOBRANCHES*; as the pipe-fish, and pegasus.

ORDER III. *THE MALACOPTERYGIENS*; as the salmon, herring, sein-fish, pike, carp, loche, silurus; cod, turbot, sole, remora, eel.

ORDER IV. *THE ACANTHOPTERYGIENS*; as the perch, mackerel, dolphin.

DIVISION II. MOLLUSCA.

Six Classes, principally constituted from the organs, and mode of progression.

CLASS I. *THE CEPHALOPODES*; as the cuttle-fish, and nautilus.

CLASS II. *THE PTÉROPODES*; as the clio, cleodore, and hyalea.

CLASS III. *THE GASTEROPODES*; as the slug, snail, and limpet.

CLASS IV. *THE ACÉPHALES*, (without heads); as the oyster, and muscle.

CLASS V. *THE BRACHIOPODES*; as the lingula, and terebratula.

CLASS IV. *THE CIRRHOPODES*; as the barnacle.

DIVISION III. ARTICULATED ANIMALS.

Four Classes.

CLASS I. *ANNÉLIDES, OR WORMS.*

ORDER I. THE TUBICOLES, forming a calcareous tube around them; as the scopula, sabella, and terebella.

ORDER II. THE DORSIBRANCHES, the limbs diffused over the body; as the néréïde and aphrodite.

ORDER III. THE ABRANCHES, (without limbs); as the earth-worm and leech.

CLASS II. THE CRUSTACEOUS.

Five orders, formed from the number, or position of their organs of motion.

ORDER I. THE DÉCAPODES; as the crab, lobster, and prawn.

ORDER II. THE STOMAPODES; as the squill.

ORDER III. THE AMPHIPODES; as the gammarus.

ORDER IV. THE ISOPODES; as the wood-louse.

ORDER V. THE BRANCHIOPODES; as the monocullus.

CLASS III. THE ARACHNIDES, OR SPIDER TRIBE.

Two orders, formed from respiration being effected by pulmonary cells; or by tracheæ, or openings in the skin.

ORDER I. THE PULMONAIRES; as the spider, tarantula, and scorpion.

ORDER II. THE TRACHÉENNES; as the phalangium, and mite.

CLASS IV. INSECTS.

Twelve orders, derived principally from the number of their feet and wings.

ORDER I. THE MYRIAPODES, having numerous feet; as the iulus, centipes.

ORDER II. THE THYSANOURES, having appendages to their tails; as the lepisma, or wood-fish, and podura.

ORDER III. THE PARASITES; as the louse.

ORDER IV. THE SUCEURS; as the flea.

ORDER V. The COLÉOPTÈRES, having cased wings; as the carabus, beetle, lady-bird, glow-worm.

ORDER VI. THE ORTHOPTÈRES, having straight wings; as the earwig, locust, grasshopper, and mole cricket.

ORDER VII. THE HÉMIPTÈRES, or half-winged; as the bug, the water-scorpion, lantern-fly, aphis, and cochineal.

ORDER VIII. THE NÉUROPTÈRES, having net-work wings; as the dragon-fly, and ephemera.

ORDER IX. THE HYMENOPTÈRES, having membranous wings; as the ichneumon, ant, sphex, wasp, and bee.

ORDER X. THE LEPIDOPTÈRES, having scaly wings; as the butterfly and moth.

ORDER XI. THE RHIPIPTÈRES, having fan-like wings; as the xenos, and stylops.

ORDER XII. THE DIPTÈRES, having two wings; as the gnat, and house-fly.

DIVISION IV. ZOOPHYTES. Four Classes.

CLASS I. THE ECHYNODERMES; spined skin; as the star-fish, and echinus.

CLASS II. THE INTESTINAUX, or intestinal animals; as the tænia, ascaris, and hydatid.

CLASS III. THE ACALÈPHES, or sea-nettle; as the sea-anemony, and medusa.

CLASS IV. THE POLYPES, or many-feeted; as the hydra, coralline, and sponge.

CLASS IV. THE INFUSOIRES, found in animal and vegetable infusions; as the wheel animal, and proteus.

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